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VOLUME XLI NUMBER 3

THE

ASTROPHYSICAL JOURNAL

An International Review of Spectroscopy and Astronomical Physics

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THE UNIVERSITY OF CHICAGO PRESS
CHICAGO, ILLINOIS, U.S.A.

AGENTS
THE CAMBRIDGE UNIVERSITY PRESS, LONDON AND EDINBURGH
KARL W. HIERSEMANN, LEIPZIG
THE MARUZEN-KABUSHIKI-KAISHA, TOKYO, OSAKA, KYOTO

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The Astrophysical Journal is published by the University of Chicago at the University Press during each month except February and August. ¶ The subscription price is $5.00 per year; the price of single copies is 65 cents. Orders for service of less than a half year will be charged at the single-copy rate. ¶ Postage is prepaid by the publishers on all orders from the United States, Mexico, Cuba, Porto Rico, Panama Canal Zone, Republic of Panama, Hawaiian Islands, Philippine Islands, Guam, Samoan Islands, Shanghai. ¶ Postage is charged extra as follows: For Canada, 30 cents on annual subscriptions (total $5.30), on single copies, 3 cents (total 68 cents); for all other countries in the Postal Union, 62 cents on annual subscriptions (total $5.62), on single copies, 11 cents (total 76 cents). ¶ Remittances should be made payable to The University of Chicago Press, and should be in Chicago or New York exchange, postal or express money order. If local check is used, 10 cents must be added for collection.

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Claims for missing numbers should be made within the month following the regular month of publication. The publishers expect to supply missing numbers free only when they have been lost in transit.

Business correspondence should be addressed to The University of Chicago Press, Chicago, Ill.

Communications for the editors and manuscripts should be addressed to the Editors of THE ASTROPHYSICAL JOURNAL, The University of Chicago, Chicago, Ill.

Entered as second-class matter, January 17, 1895, at the Post-office at Chicago, Ill., under the act of Congress of March 3, 1879

THE
ASTROPHYSICAL JOURNAL
AN INTERNATIONAL REVIEW OF SPECTROSCOPY
AND ASTRONOMICAL PHYSICS

VOLUME XLI APRIL 1915 NUMBER 3

AN OPTICAL PERIODOGRAPH[1]

By A. E. DOUGLASS

In a preceding article[2] the writer described a photographic device for producing a "periodogram" which promised to have some of the usefulness predicted by its proposer, Professor Arthur Schuster. By its aid the coarser and more persistent fluctuations of value in a series of measures, such as annual sun-spot numbers or rainfall, can be observed with a slight expenditure of mechanical work in plotting, but without mathematical analysis. The experience with that device and with the peculiar variations in the sun-spot numbers strongly indicated the need of more rigid analysis. It became evident indeed that not merely every possible period should be tried as a whole but that every period should be tried in detail and its varying application throughout the entire series of observations made evident and measurable. This need of detailed analysis was in the last article met to a slight extent by a system of multiple plotting in which the solid white curve was repeated many times parallel to itself with regular and equal dark intervals between. Each repetition of the curve also was displaced by a constant amount to one side of its predecessor. Periods then showed themselves by rows of crests which immediately became evident.

[1] Prepared with assistance from the Elizabeth Thompson Science Fund.

[2] *Astrophysical Journal*, **40**, 326, 1914, in which a number of references are given.

Secondary variations showed by lack of straightness in these rows. Any individual row was in effect nothing more than a plot of departures from the constant period represented in the diagram by a vertical line. The duplication of rows assisted the eye in judging of straightness. In the recent improvements of the apparatus this duplicate plotting has been made entirely automatic.

PROCESS

The curve is rendered a solid white area on a black background (or the reverse). The white area showing is limited if necessary by long, straight black mats. To a large camera lens

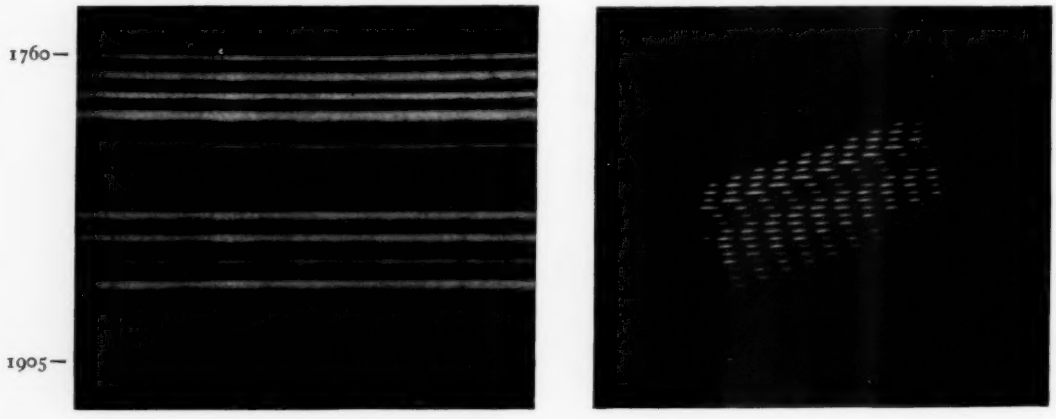

FIG. 1.—"Sweep" of sun-spot numbers and analysis of same by the optical periodograph, showing variations in the period from less than 10 years to nearly 14. Variations are indicated by lack of straightness in the vertical rows.

a cylindric lens is added, by which, in place of a simple image, the curve at the focus is swept or spread across the field, producing a large number of parallel lines, each one proportional in intensity to the height of its corresponding point in the curve (see Fig. 1). Any straight line whatever in any direction across this "sweep" truly represents the original curve, not as a rising and falling line, but in varying light-intensity. A plate with equally spaced parallel opaque lines called the analyzer or analyzing plate is placed in the plane of this "sweep." When the analyzer is turned at a

small angle to the lines of the sweep, each transparent line shows the full curve in its varying intensities. These numerous reproductions are all parallel to each other, separated by equal dark lines, and each one is displaced longitudinally with reference to its neighbors (thus presenting the characteristics of the multiple plot). By twisting the analyzer with reference to the sweep, while the two remain in parallel planes, different periods are tested; for as the analyzer twists, each reproduction varies in respect to its length and its displacement from its next adjoining neighbors, above and below. When a period is formed, it shows itself by rows of dark and light spots in alignment more or less perpendicular to the analyzing lines, as in Figs. 1 and 5. These light and dark rows are analogous to interference fringes and are identical with the elaborate but provokingly useless designs on a wire screen in front of its reflection in a window or with the parallel fringes when two sets of parallel lines are held at a slight inclination to each other.[1]

APPARATUS

The curve is now usually reproduced by preparing a narrow strip of tracing-cloth of barely sufficient width to cover its variations. This is pinned over the curve and all area between the curve and one edge of the cloth strip is painted opaque. The strip is then mounted in a narrow horizontal opening in the window and slightly indirect illumination applied so that the translucent parts give out full and even light.

A stand on casters carries the remainder of the apparatus, whose distance from the curve may thus be varied from 3 to 50 feet. A 6-inch stereopticon lens of $1\frac{1}{2}$-inch aperture casts an image of the curve, about 1 inch in length. Between the curve and the lens and almost in contact with the latter the cylindric lens is inserted with axis parallel to the curve. This lens is concave, of 5-inch focus, and cut 1 inch wide in line with the axis and $1\frac{1}{2}$ inches in length at right angles to the axis. The concave side faces the

[1] W. H. Roever has used somewhat similar interference patterns to illustrate very beautifully certain lines of force (*Bulletin of the Mount Weather Observatory*, 6, 195).

curve. In mounting this lens, about $\frac{1}{8}$ inch is cut off from each dimension.

In the focus of the lens, which may be called the analyzing field, is placed the analyzing plate. It is mounted in the center of a circular disk which rests on wheels and rotates about its center. Four different plates have been made to meet different requirements, the spacing from center to center of the opaque lines being respectively about 0.5, 1.0, 2.0, and 4.0 mm. (It would be well to have intermediate spacings of about 0.7, 1.4, and 2.8 mm in addition.) Considerable difficulty was experienced in making these plates. They are preferably on glass with strong contrast between the opaque and transparent parts. An unexposed dry plate was cleared by a hypo bath and dried. India-ink lines on the film were tried but proved not satisfactory as they were very difficult to produce with perfect regularity and in addition quickly cracked. The grating was finally produced by photographing a 10-foot sheet of co-ordinate paper whose face was covered by line after line (165) of black gummed paper. The co-ordinate lines permitted the spacing to be done with sufficient exactness. The width of the transparent space was throughout three-tenths of the distance from center to center (except in the 4 mm lines when the transparent part is only 0.21; a still smaller space would probably be advantageous). This was carefully photographed by a good lens at three different distances. Two glass prints were made from each negative and then each pair mounted face to face so as

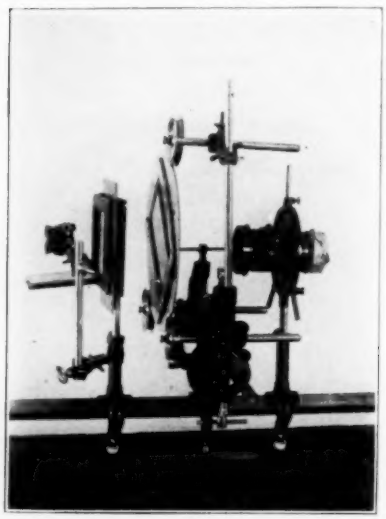

FIG. 2.—Analyzing parts of apparatus with which illustrations in this article were made. From right to left the parts are: cylindric lens, projecting lens, analyzing plate, camera-back and eye-lens. In photographing, the camera-back is moved close to the analyzing plate; in measuring periods, it is replaced by a small position micrometer.

to give great density in the opaque parts. These final plates are 4×5 inches in size and can be interchanged in the rotating disk. Back of the analyzing plate is mounted an eye-lens for visual examination. This lens is about 1 inch in diameter and of 3 inches focus. When a photograph is desired, a camera-back using a $3\frac{1}{4}\times4\frac{1}{4}$ plate and holder can be put close to the analyzing plate. This arrangement is shown in Fig. 2; the plate-holder, however, in the photograph is moved back a few inches so as not to hide the analyzing plate.

In order to measure the position angle of fringes and obtain other data needed for calculating any period indicated, a small position micrometer can be substituted for the camera-back behind the analyzing field. To get the field reproduced in the plane of the micrometer threads a 3-inch converging lens of 10 or 15 inches focus is placed in or close to the field. This brings the bundle of rays within the compass of a small short-focus lens immediately in front of the micrometer which casts an image of the field in the plane of the threads. Thus the position angle and separation of fringes may be measured, together with the scale of the image of the curve, the spacing of the analyzing lines, and the angle between the analyzing lines and the sweep-lines of the curve. These data are more than are needed to determine the period. Indeed the separation of the fringes may be used as an extra check upon the period found; however, it is not as sensitive as the position angle of the fringe.

Fig. 2 shows the analyzing parts of the periodograph mounted as above described and constructed of ordinary laboratory standards. The only parts at all out of the ordinary are the cylindric lens, which may be obtained at a wholesale optician's, and the analyzing plate.

THEORY

The formula for the period is very simple.

Let y = length of curve in years or other time unit employed
l = length of curve image in cm or other unit of length (across sweep)
s = spacing center to center of analyzing lines in unit of length

Then

$$\frac{l}{s} = \text{number of lines in curve when lines are parallel to sweep}$$

$$\frac{ys}{l} = \text{number of years in 1 line when lines are parallel to sweep}$$

Now taking analyzing lines $\overline{aa'}$ and $\overline{bb'}$ in Fig. 3 as horizontal and letting the sweep be inclined at a small angle δ with the analyzing

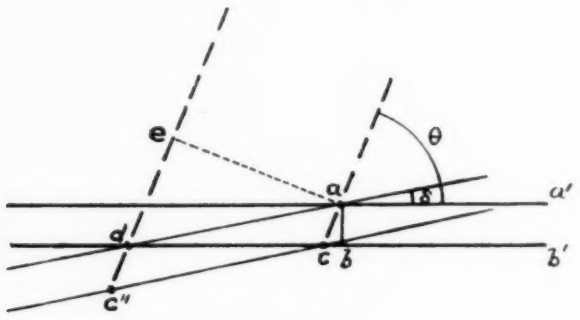

FIG. 3

lines, the number of lines required to cross the sweep in the direction ab will be increased and hence the value in years will be decreased; hence

$$\frac{ys}{l} \cos \delta = \text{years per line from } a \text{ to } b$$

If the fringe is perpendicular to the analyzing lines, its period is the distance $\overline{ab}$ in years and we have for this special case:

$$p_1 = \frac{ys}{l} \cos \delta$$

If, however, the fringe takes some other slant as the direction $\overline{ac}$, making the angle θ with the analyzing lines, then the period desired is the time in years between a and c. That equals the time between a and b less the time from b to c. Now $\overline{bc}$ in years would equal $\overline{ab}$ cot θ except for the fact that the horizontal scale along $\overline{bc}$ is greater than the vertical scale along $\overline{ab}$ in the ratio $\frac{\cos \delta}{\sin \delta}$ and

therefore a definite space interval along it means fewer years in the ratio of $\frac{\sin \delta}{\cos \delta}$. Hence we have:

$$\overline{bc} \text{ (in years)} = \overline{ab} \text{ (in years)} \tan \delta \cot \theta$$

or

$$P = p_1(1 - \tan \delta \cot \theta)$$

The period thus worked out for Fig. 5*a* is:

$$P = 1.91 - 0.41 \cot \theta$$

and for Fig. 5*b*

$$P = 3.87 - 1.01 \cot \theta$$

The separation of the fringes needs to be known at times in order to find whether one or more actual cycles are appearing in the period under test, as in Fig. 5*b*. In Fig. 3

$$\overline{ab} = s$$

$$\overline{ad} = \frac{s}{\sin \delta}$$

$$\overline{ae} = \frac{s \sin (\theta - \delta)}{\sin \delta}$$

which is the width required.

RANGE OF PERIODS COVERED

There are three ways of testing different periods, namely, twisting the analyzer, changing the scale of the analyzer, and changing the scale of the sweep. The first is a very sensitive method; a large angular change, say 45°, covers a relative range of 100–143. The next size of analyzing plate then carries it from 200 to 286 leaving untested the gap between 143 and 200; hence one sees the advantage of an intermediate size to cover this range. As it was, the gap was covered by moving the lens and the plate on its roller stand which changes the scale of the sweep. Thus twisting the analyzer covers only a short range, but change of scale, whether of the analyzer or of the sweep, may be made to cover any desired range whatever. These two offer excellent checks on each other and should both be used.

SUGGESTIONS FOR PRODUCING A PERIODOGRAM

There appear to be several ways of producing a periodogram, all of which, however, use an additional camera with cylindric lens, a slit in the focal plane, and a plate-holder moving past it by clockwork, after the method described in the preceding article. If the desired range is not great, such prints as in Fig. 5 may be used as the source of light, mounted to rotate by clockwork about a central axis. Or the camera and appurtenances may be mounted in place of the camera-back in Fig. 2 and made to take a photograph as the analyzing plate is turned. The best suggestion, however, is to mount the camera as just described and then take the photograph while changing the scale of the "sweep" through a large range by varying the distance between the mounted curve and the projecting lens. This involves changing the focus of the projecting lens at the same time, which is less simple but not impossible. In this way any desired range would be covered in an instructive and convenient manner. In the author's opinion the most valuable use for the full periodogram will be its aid in presenting results to the reader. Although it may not tell the whole story, yet it covers a large field in a very small space.

A PRACTICAL APPLICATION OF THE PERIODOGRAPH

A period of about 25 months was observed over the eastern and central states by Clayton in 1884–1885[1] in rainfall for the preceding decade. It did not persist and the investigation of it was held in abeyance. Recently a periodic variation in eastern temperatures ranging from 16 to 38 months was studied by Arctowski,[2] who identifies it with the period found by Clayton and entertains the idea that a period may vary. More recently the writer suspected a short period in growth of vegetation both in America and in Northern Europe. It seemed to show in the annual growth of trees in many regions but appeared especially marked in Central Sweden, and only somewhat less so in the Vermont region. The period or "seesaw" indicated by the trees was either 21 or 28 months. In order to distinguish between these alternatives

[1] *American Meteorological Journal*, **1**, 130, 528; and conversation.

[2] *Bulletin of the American Geographical Society*, **45**, 120, 1913.

the rainfall near Windsor, Vermont, was compiled[1] from neighboring records and investigated with the periodograph. All possible periods were tested, but those shown in Fig. 5 were by far the most promising. These diagrams indicate a mean result of about 28 months as the predominating period, but show that this value is not perfectly constant. If this were constant the fringes would be straight. Instead of that the whole fringe is slightly displaced near the center for a considerable period of time. This result of

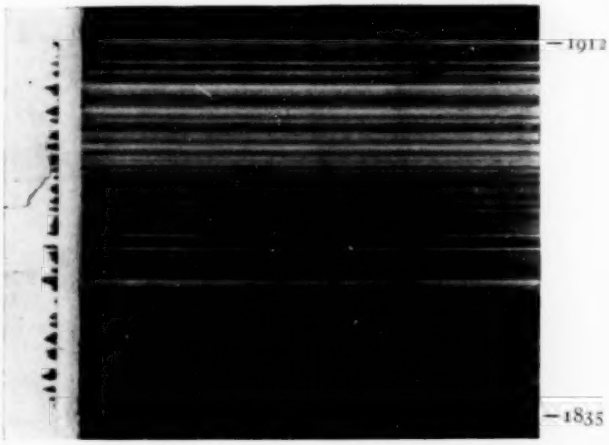

FIG. 4.—Curve of rainfall at Windsor, Vt. (negative), and its "sweep" (positive) from 1835 to 1912.

28 months is believed to be the same as Clayton's result of 25 months, because during the ten years or so preceding 1884 there is a little bend in the fringe which shows that the period was then distinctly less than 28 months, even possibly as low as 25 or 26 months. Arctowski's large allowance of variation easily includes the result here obtained. Hence we find some cause for believing in a period which is not constant. In applying rigid periods this

[1] The curve, shown on a small scale in Fig. 4, was derived as follows: The record of rainfall for every 3 months was smoothed by 4-term overlapping means to get rid of seasonal change. It was then smoothed by Hann's formula (the smoothing here mentioned can be done in the focusing), and "truncated" by a slightly curving line which eliminated coarse variations of ten years or more, leaving the smaller variations. Fig. 5*d* was made directly from this curve. Figs. 5*a*, *b*, and *c* were photographed from a dense photographic negative of the curve.

is likely to be overlooked. The possibility inferred from these photographic results then is that the study of slightly variable periods might open up added fields of knowledge of meteorological phenomena. To the investigation of such periods, the instrument here described is especially adapted.

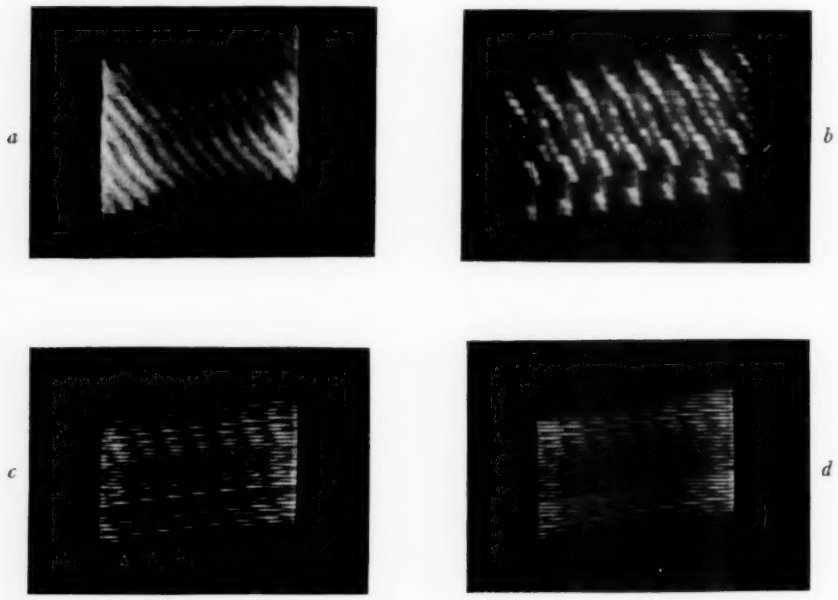

FIG. 5.—Various analyses of rainfall at Windsor, Vt., by the periodograph, showing variation of a suspected 2.3 year period (1912 at top, 1835 at bottom of each). *a*, out of focus, 2.3 year fringes; *b*, out of focus, tested for a 5-year period, it again shows 2.3 year fringes; *c*, in focus, with slight variations of scale and angle from *a;* taken from white curve on black background; *d*, taken from black curve on a white background.

APPLICATION TO THE STUDY OF TREE GROWTH

Fig. 6 shows the application of the periodograph to the analysis of a tree-growth curve. The 500-year record of the yellow pine in northern Arizona, derived from the annual rings, was corrected for decrease of growth with age, reduced to percentages of its own mean, smoothed by Hann's formula, slightly "truncated" to eliminate long fluctuations of over 20 years, and then treated as

described above for the rainfall-curves. The result is shown in the figure. A period varying from 5.1 to 6.3 years seems to be traceable throughout. Taken from end to end it averages 5.7 years. In the later centuries it is evidently a submultiple of an approximate 21-year period. Between 1750 and 1790 a period of 4.3 is shown in this analysis, and from 1860 to 1900 a 7-year period is manifest.

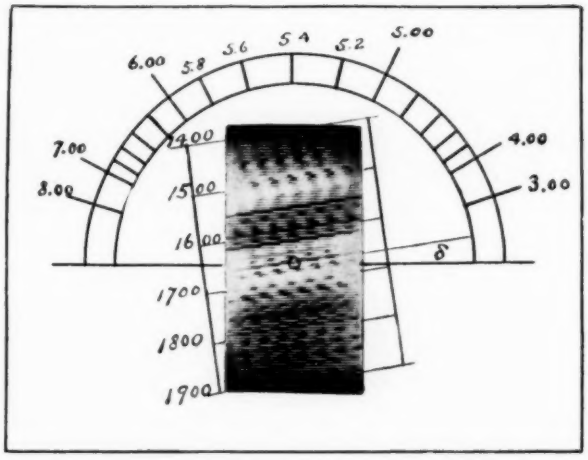

FIG. 6.—Analysis of 500 years of tree-growth record in Arizona to show periods between 3 and 8 years; dates are given on the left; the numbers on the semicircle at the top give the length in years of any period denoted by a fringe extending in that direction.

The vertical fringes suggest a period varying between 5.1 and 6.3 years, best developed between A.D. 1400 and A.D. 1650.

MANIPULATION; ACCURACY

While the optical periodograph has worked satisfactorily in the cases already tested, it has not been free from difficulties. The matter of focus is important. Displacement of the photographic plate a centimeter or two back of the analyzing plane produces a deceptive certainty of result, for the effect of the cylindric lens is to extend the vertical and diminish horizontal alignments. This may be seen in the difference between Figs. 5*a* and 5*c* since the two were taken under nearly the same conditions, but the former is somewhat out of focus. Nevertheless, the actual periods

measured in Figs. 5*a* and 5*b* agree within 2 per cent with those in Figs. 5*c* and 5*d*.

Again, for consistent results the analyzing plate must be close to the focal plane of the sweep. If it is not, then distortion is produced in the micrometer field. In order to bring it in the proper place a microscope with a 1″ or 2″ objective is focused on the analyzing lines while the projection lens is moved back and forth till the sweep-lines are perfectly in focus. After a photograph has been made in the focal plane, then it is proper to take a print of it out of focus, using a large circular source of light, in order to get any desired smoothing effect.

The analysis of a curve and the analysis of its negative should give concordant results. Yet it would not be surprising if in some cases they do not. In the illustration cited Fig. 5*c* is made from a lantern slide showing a transparent white curve against a black background, and Fig. 5*d* is given to show the same results with a curve plotted black on white paper background. The numerical results of measurements on equivalent patterns made with the position micrometer just before the photographing are as follows:

	Period Fig. 5*c*	Period Fig. 5*d*
About 1851 to about 1881	2.39 years	2.34 years
" 1881 " " 1887	2.14 "	2.13 "
" 1887 " " 1902	2.46 "	2.38 "
Mean Period through Entire Series 1835–1912		
A to G	2.303 years	2.274 years
A_1 " G	2.342 "	2.360 "
A_2 " G	2.505 "	2.460 "

These differences, amounting to between 1 and 2 per cent, are doubtless due to different estimates of the direction of fringes.[1]

In changing from a curve expressed in ordinates to one expressed in light-intensities, there is no great drawback for this purpose, although precision is lost. The chief loss is in accuracy of photographic values, for relative intensities will vary slightly with the plate, the exposure, and the time and character of the development.

[1] The ideal condition will perhaps use neither positive nor negative type of curve but a plot, on a neutral tone or gray, of departures from a mean value, positive differences being white, and negative being black.

The illustrations here given and perhaps usually given will tell only a part of the story. It would require a motion picture to tell the whole. The operator at the instrument can see the whole, for it unfolds itself before him as the size of the sweep starting at a minimum increases several hundred per cent. In picking out individual positions for photographs, his own judgment, or personal equation, or prejudice even may enter. But it is a question if they can do material harm, for it seems to the writer almost impossible to estimate offhand what period is being indicated by any fringe on account of the different scales and angles entering every new combination. However, in addition to special photographs, others taken at regular intervals throughout the entire range would give confidence to the reader. A periodogram, though helping very materially, is not completely satisfactory because it may fail to show some promising periods which are not perfectly constant. It is probable that a periodogram of Fig. 5*a* would largely lose the periodic effect there shown.

Again, there may be much uncertainty and perhaps even mistake in judging of the alignments, but the reader to whom the pictures are presented can judge for himself. In fact, the real advantage in this method of analysis is that alternative alignments indicate real uncertainties in the solution, which the reader himself is perfectly able to see and estimate.

In studying diagrams, fringes are emphasized by viewing the print in a slanting direction.

No practical attempt has yet been made to analyze a curve full of sharp variations such as an unsmoothed rainfall curve. A slight variation in focus may be used to smooth such irregularities.

CONCLUSION

In answer to the need of considering secondary variations in any suspected periodic variations, an instrument has been constructed by which, in an hour or two after plotting, the investigator may view all possible periods in a curve and their variations and begin measuring and photographing the promising ones. This optical periodograph is not yet complete, but it is believed that even now it will have some use in preliminary tests of periodic variation

and in some cases save long computations or in others show where rigorous investigation should be applied. Should it prove desirable to enter upon extended studies of slightly varying periods, this instrument gives a rapid method of approaching the work.

UNIVERSITY OF ARIZONA
February 5, 1915

LIST OF STARS WITH PROPER MOTION EXCEEDING 0".50 ANNUALLY[1]

By ADRIAAN VAN MAANEN

Since the publication, by Porter[2] and Kobold,[3] of the lists of stars having proper motions greater than 0".50 annually, and since the appearance of Bossert's[4] catalogue of proper motions of 2641 stars, there have been published several notes on stars of large proper motion. The following list (Table I), which has been based on all these sources, is, I hope, complete up to 1914.

In the first column is given the current number; in the second and third columns the name and number in the *B.D.* or *C.P.D.* The fourth column contains the magnitude. To have these as homogeneous as possible it seemed best to give the magnitudes of the *B.D.* and *C.P.D.* For the companions of double stars, which are not given in these sources, the difference as given in Burnham's *General Catalogue* is added to the magnitude of the principal stars. For stars not contained in any of these catalogues I have given the magnitudes as given by the authors of the proper motions. These are marked by an asterisk.

In the fifth column is given the spectrum as determined by W. S. Adams (in an unpublished list, for the use of which I feel greatly indebted to Mr. Adams) or by Miss Cannon.[5] The sixth and seventh columns contain α and δ for the equinox of 1900.0; and the eighth and ninth columns the amount and the direction of the proper motion; while the tenth column gives the authority. The last column finally gives some remarks, regarding uncertainties in the proper motions, and, in the case of double stars, the number in Burnham's *General Catalogue*.

[1] *Contributions from the Mount Wilson Solar Observatory*, No. 96.

[2] *Astronomical Journal*, **12**, 25, 1892.

[3] *Der Bau des Fixsternsystems*. Vieweg und Sohn, 1906.

[4] *Catalogue d. mouv. propres de 2641 étoiles*, 1896.

[5] *Harvard Annals*, **50**, 1908.

TABLE I

No.	Name	*B.D.* or *C.P.D.*	Mag.	Spec.	α 1900	δ 1900	μ	φ	Authority	Remarks
1	Gi.Z. 16730	−68° 3597	9.0	.....	0h 0m16s	−68° 22′	0″.53	204°.9	Rist.	
2	Lal. 47231[1]	+45 4408	8.3	K5:	0 0 24	+45 16	0.90	98.3	Po.	β 12740
3	Lal. 47231[2]	.....	8.3	.....	0 0 24	+45 16	0.89	102.9	β	β 12740
4	Lal. 9721	−49 11858	6.2	G	0 1 8	−49 38	0.53	94.8	Boss	
5	β Cass	+58 3	2.2	F5	0 3 50	+58 36	0.54	110.4	Au.	
6	A. G. Hels. 38	+64 3	7.0	.....	0 3 57	+64 31	0.88	86.9	Schulhof	
7	A. G. Chris. 15	+66 7	9.0	.....	0 5 22	+66 35	0.91	84.0	Schulhof	
8	Lal. 248	+43 44	8.1	Ma	0 12 40	+43 27	2.82	81.8	Ps.	
9	ζ Toucani	−65 13	5.1	F8	0 14 52	−65 28	2.05	55.9	Po.	
10	A.W. 120	−27 23	8.4	.....	0 17 0	−27 16	0.52	74.7	Rist.	
11	Lal. 475	−27 25	8.1	.....	0 19 20	−27 35	0.70	86.7	Po.	
12	Lac. 75	−51 48	7.2	.....	0 19 48	−51 35	0.57	122.0	Po.	
13	β Hydrae	−77 16	3.3	G	0 20 30	−77 49	2.27	81.9	Po.	
14	Lac. 127	−35 60	7.0	.....	0 28 50	−35 32	0.53	180.0	Po.	
15	Pi. 0h130	−25 64	6.5	G5	0 32 13	−25 19	1.41	91.2	Po.	
16	Lal. 999	+ 2 84	7.5	G1	0 34 0	+ 2 35	0.79	68.3	Po.	
17	54 Piscium	+20 85	6.2	K1	0 34 10	+20 43	0.61	231.6	Ps.	
18	Lal. 1045	+39 154	7.0	K3	0 35 20	+39 39	0.81	152.1	Po.	
19	Lal. 1065	−24 60	6.9	K	0 35 31	−24 21	0.79	114.0	Po.	
20	Lac. 172	−60 46	6.1	K	0 35 45	−60 1	1.00	64.5	Po.	
21	Lal. 1198	+ 1 131	8.2	K4	0 39 57	+ 1 15	0.63	180.9	Po.	
22	η Cass	+57 150	3.8	F8	0 43 3	+57 17	1.19	113.8	Au.	β 426
23	Comp. to η Cass	.....	7.4	.....	0 43 3	+57 17	1.19	113.8	Au.	β 426
24	Lal. 1299	+ 4 123	6.0	K1	0 43 8	+ 4 46	1.37	146.9	Au.	
25	Groom. 145	+69 45	7.8	K0	0 43 17	+69 54	0.54	113.4	Greenwich	
26	Lal. 1353	−23 95	7.4	.....	0 44 27	−23 46	0.55	76.2	Po.	
27	Lac. 239	−31 92	7.4	.....	0 48 6	−30 54	0.71	84.3	M.N.	
28	A. G. Chris. 174	+68 60	9.1	.....	0 50 21	+68 31	0.73	111.0	Schulhof	
29	Lal. 1799	+ 4 158	8.3	K6	0 57 12	+ 4 31	0.50	59.6	Po.	
30	A. G. Hels. 914	+63 137	8.7	.....	1 0 18	+63 24	1.62	80.1	Bellamy†	

† Miss E. F. Bellamy, *Astronomische Nachrichten*, **195**, 359, 1913.

31	μ Cass	+54	223	5.7	G3	1h 1m7	+54° 26′	3″.73	114°.9	Au.
32	Lal. 1964	+22	176	8.4	K5	1 2 14	+22 26	0.52	167.9	Po.
33	Cp. St. St. 352	−51	162	8.6	.....	1 2 21	−51 31	0.50	92.1	Cape
34	Lal. 1966	+60	170	7.8	F3	1 3 18	+61 1	0.69	90.0	Po.
35	Anonymous	.....	.....	13.0*	.....	1 6 1	−72 46	0.73	54.8	Pickering
36	ν Phoenicis	−46	127	6.1	G	1 10 40	−46 4	0.71	76.2	Po.
37	W.B. 1h161	− 1	167	8.0	G8	1 13 32	− 1 23	0.54	123.7	Po.
38	La. 2387	− 9	256	8.5	.....	1 14 1	− 9 27	0.57	208.3	Po.
39	W.B. 1h262	+30	206	8.8	.....	1 15 50	+30 49	0.52	98.0	Rist.
40	Lal. 2450	+17	197	7.9	G0	1 16 52	+18 10	0.57	90.0	Po.
41	W.B. 1h356	+17	202	8.8	.....	1 19 26	+17 59	0.67	106.0	Berlin A
42	Lal. 2682	+20	226	7.8	K1	1 23 35	+21 13	0.53	111.2	Po.
43	Lal. 2975	+28	271	8.5	.....	1 32 43	+29 4	0.54	118.6	Po.
44	Lal. 3022	+27	262	7.8	G7	1 33 56	+27 36	0.53	75.7	Po.
45	Lal. 2966	+66	145	7.4	G4	1 34 11	+66 25	0.76	107.7	Po.
46	Lal. 3054	+41	328	5.3	F	1 35 42	+42 7	0.82	100.5	Po.
47	A.Oe. 1867-8	+63	229	8.2	.....	1 36 46	+63 20	0.64	206.9	Rist.
48	Lal. 3128	+19	279	5.3	F	1 37 4	+19 47	0.73	204.1	Ps.
49	Lal. 3153	−18	287	7.2	.....	1 37 22	−18 24	0.54	93.8	R3
50	τ Ceti	−16	295	3	K	1 39 25	−16 28	1.95	296.1	Ps.
51	Pi. 1h159	+63	238	6.1	K1	1 40 31	+63 22	0.62	112.8	Po.
52	A.Oe. 1137-8	−23	215	9.0	.....	1 48 2	−22 56	0.92	90.0	Po.
53	χ Eridani	−52	241	5.8	G5	1 52 4	−52 6	0.72	65.5	Po.
54	Cp. St. St. 647	−41	183	7.4	.....	1 56 18	−41 12	0.58	138.7	Cape
55	Lal. 3922	− 1	293	7.5	G0	2 2 30	− 1 5	0.50	220.9	Po.
56	Lac. 661	−51	282	7.1	G	2 6 24	−51 19	2.28	70.5	Po.
57	Lal. 3987	+67	191	7.8	.....	2 7 31	+67 13	0.56	122.6	Ps.
58	W.B. 2h95	− 1	306	8.3	F5	2 9 28	− 1 40	0.97	95.3	Po.
59	Lal. 4141	+23	303	6.5	G4	2 9 41	+23 49	0.60	106.3	Ps.
60	δ Trianguli	+33	395	5.0	G	2 10 57	+33 46	1.15	101.5	Ps.
61	Lal. 4268	+ 1	410	5.8	F5	2 12 50	+ 1 17	0.49	44.8	Po.
62	A.Oe. 2618	+70	169	8.5	.....	2 14 3	+70 43	0.58	69.6	Greenwich
63	A. G. Christ. 416	+68	166	7.5	.....	2 14 30	+68 18	0.87	92.3	Schulhof‡

‡ Schulhof marks the P.M. as uncertain, *Bulletin Astronomique*, **27**, 206, 1910.
The Greenwich second *9Y Cat.* gives $\mu = 0''.12$, $p = 60°.9$.

TABLE I—*Continued*

No.	Name	*B.D.* or *C.P.D.*	Mag.	Spec.	α 1900	δ 1900	μ	φ	Authority	Remarks
64	Lal. 4338	−26° 214	7.2	G	$2^h14^m30^s$	−26° 25′	0″.50	330°.9	Po.	
65	A.W. 1327	−17 484	9.4	.....	2 26 40	−17 26	0.56	90.0	Po.	
66	Pi. 2^h123	+ 6 398	6.5	K6	2 30 36	+ 6 25	2.34	51.8	Po.	
67	Lal. 4855	+30 421	7.3	Go	2 32 35	+30 24	0.60	228.4	Po.	
68	A.Oe. 1739.41	−30 324	7.8	.....	2 36 17	−30 34	0.66	90.0	Po.	
69	A.Oe. 1753	−30 327	9.0	.....	2 37 22	−30 44	0.51	127.4	Po.	
70	A. G. Bonn 2435	+45 669	9.0	.....	2 44 54	+45 35	0.64	119.2	Ling	
71	A. G. Berlin A 767	+15 395	9.0	.....	2 45 2	+15 19	0.53	141.1	Berlin A	
72	Comp. to Anon. $2^h45^m54^s+22°37'$	.....	12.1*	.....	2 45 44	+22 38	0.87	355.6	β	
73	Anonymous	.....	10.4*	.....	2 45 54	+22 37	0.71	241.7	Puiseux	
74	W.B. 2^h927	+ 5 435	8.2	G8	2 55 15	+ 5 36	0.68	102.8	Po.	
75	Lal. 5490	+61 513	6.7	G3	2 55 58	+61 20	1.01	131.4	Po.	
76	ε Fornacis	−28 302	6.6	G	2 57 19	−28 28	0.50	145.7	Po.	
77	ι Persei	+49 857	4.3	G	3 1 51	+49 14	1.25	92.7	Au.	
78	Lal. 5761	+25 495	7.9	A3p	3 2 32	+25 58	0.90	191.6	Po.	
79	Lal. 5986	−29 362	4.2	F	3 7 49	−29 23	0.73	25.2	Au.	
80	W.B. 3^h113	+ 8 482	7.8	Ko	3 9 22	+ 8 37	0.62	131.7	Po.	
81	ξ_1 Reticuli	−63 217	6.4	G	3 15 36	−62 57	1.48	65.2	Po.	
82	Lac. 1060	−43 354	5.6	G5	3 15 56	−43 27	3.05	75.5	Po.	
83	ξ_2 Reticuli	−62 265	5.6	F8	3 16 2	−62 53	1.44	63.6	Po.	
84	Lal. 6320	− 5 642	7.9	K6	3 20 4	− 5 42	0.86	198.2	Po.	
85	Lal. 6429	−20 643	8.0	.....	3 23 19	−20 10	0.61	61.8	Po.	
86	Lac. 1143	−63 234	5.4	F5	3 27 38	−63 17	0.50	43.4	Po.	
87	ε Eridani	− 9 697	3.3	K	3 28 13	− 9 48	0.99	270.7	Au.	
88	Lal. 6665	− 0 572	4.2	G5	3 31 46	+ 0 5	0.55	205.6	Ps.	
89	W.B. 3^h617	− 3 592	7.2	F5	3 35 17	− 3 32	0.79	107.7	Po.	
90	δ Eridani	−10 728	3.3	K	3 38 27	−10 6	0.75	350.8	Au.	
91	Cp. St. St. 1228	−51 443	7.2	.....	3 40 11	−50 58	0.51	12.3	Cape	
92	Lal. 6888	+41 750	8.2	G6	3 40 12	+41 9	1.38	154.2	Po.	β 1854
93	Comp. to Lal. 6888	.....	8.8	.....	3 40 12	+41 9	1.38	154.2	Po.	β 1854
94	τ^6 Eridani	−23 414	4.5	F8	3 42 33	−23 33	0.56	198.8	Po.	

95	A. G. Nicolajew 817	+ 0°	659	8.3	.....	$3^h44^m24^s$	+ 1° 3′	0″.68	161°.4	Nicolajew	
96	Lal. 7036	+60	762	7.8	.....	3 46 27	+60 53	0.50	117.6	Po.	
97	Cp. St. St. 1272	−42	366	8.4	.....	3 47 10	−42 53	0.61	18.1	Cape	
98	Groom. 745	+75	154	8.2	K4	3 48 24	+75 53	0.64	144.6	Po.	
99	Lal. 7443	+34	796	8.5	G5	3 56 32	+35 2	2.19	128.1	Po.	
100	A.W. 2324	−21	784	9.1	.....	4 2 12	−21 6	0.71	177.4	Rist.	
101	A. G. Berlin B 1366	+21	607	8.9	.....	4 8 36	+22 7	0.51	130.9	Berlin B	
102	o^2 Eridani	− 7	780	4.7	G5	4 10 40	− 7 49	4.11	212.7	Po.	} β 2109
103	W.B. 4^h166	− 7	781	9.1	A0	4 10 45	− 7 49	4.11	212.7	β	
104	Comp. to W.B. 4^h166	.....	.....	10.8	.....	4 10 45	− 7 49	4.11	212.7	β	
105	Lal. 8735	+41	931	7.1	G0	4 34 31	+41 56	0.73	127.2	Po.	
106	Cp. St. St. 1594	−50	637	7.6	.....	4 43 7	−50 15	0.59	234.4	Cape	
107	Lal. 9012	+45	992	6.5	F8	4 44 22	+45 41	0.68	145.1	Po.	
108	A. G. Leiden 1812	+34	927	8.0	.....	4 51 19	+34 7	0.76	114.6	Wilkens	
109	W.B. 4^h1189	− 5	1123	6.3	K0	4 55 51	− 5 52	1.25	151.4	Po.	
110	Lal. 9599	+18	779	5.2	G	5 1 32	+18 31	0.53	86.8	Ps.	
111	W.B. 5^h87	− 9	1094	8.0	.....	5 7 8	− 9 13	0.58	185.0	Rist.	
112	C.Z. 5^h243	−44	612	9.2	G–K	5 7 42	−44 59	8.71	131.0	Kapteyn	
113	λ Aurigae	+39	1248	4.9	G1	5 12 6	+40 1	0.84	141.7	Au.	
114	Lal. 9960	− 3	1061	8.5	.....	5 14 8	− 3 11	0.73	81.3	Po.	} β 2654
115	Comp. to Lal. 9960	.....	.....	12.5	.....	5 14 8	− 3 11	0.73	81.3	β	
116	Lal. 10299	− 3	1110	8.5	K5	5 23 29	− 3 34	0.89	198.4	Po.	
117	W.B. 5^h592	− 3	1123	8.7	.....	5 26 23	− 3 42	2.23	161.7	Po.	
118	B.D. −0° 981	− 0	981	9.0	.....	5 26 35	+ 0 2	0.52	165.0	Roy	
119	Groom. 990	+51	1094	7.9	K0	5 30 24	+51 23	0.56	279.3	Po.	
120	Pi. 5^h146	+53	934	6.3	K0	5 33 14	+53 26	0.55	179.0	Po.	
121	Lal. 10797	+37	1312	7.1	K2	3 39 9	+37 15	0.72	136.1	Po.	
122	π Mensae	−80	161	6.5	G5	5 45 8	−80 33	1.28	10.8	Po.	
123	Cordoba 6886	−70	447	8.6	.....	5 45 42	−70 13	1.29	343.1	Rist.	
124	δ Leporis	−20	1211	4.3	K	5 47 1	−20 53	0.69	161.3	Ps.	
125	Lal. 11196	+13	1036	7.0	G2	5 50 21	+13 55	0.69	136.8	Po.	
126	Lac. 2106	−63	498	6.2	K	5 53 20	−63 7	0.50	17.4	Po.	
127	A. G. Berlin A 1866	+19	1185	9.0	.....	5 57 12	+19 23	0.76	128.7	Wolf	
128	B.D. +26° 1067	+26	1067	8.9	.....	5 59 43	+26 35	0.54	227.1	Wolf	
129	B.D. −21° 1377	−21	1377	8.7	.....	6 6 22	−21 49	0.73	186.0	Po.	
130	Comp. to 71 Orionis	.....	.....	11.2*	.....	6 8 32	+19 11	0.98	194.9	Lau†	

† Lau probably used Burnham's companion C in 1886 and Burnham's companion D in 1909. According to Burnham both companions have no large P.M.

TABLE I—*Continued*

No.	Name	*B.D.* or *C.P.D.*	Mag.	Spec.	α 1900	δ 1900	μ	φ	Authority	Remarks
131	Cp. St. St. 2181	−42° 915	7.4	.....	$6^h21^m21^s$	−42° 49′	0″.75	346°.6	Cape	
132	Groom. 1159	+79 212	5.5	A2	6 29 10	+79 40	0.66	186.1	Po.	
133	Gi.Z. 4158	−68 536	8.9	.....	6 32 29	−68 37	0.50	195.0	Rist.	
134	α Canis Majoris	−16 1591	1.0	A	6 40 45	−16 35	1.31	203.8	Au.	β 3596
135	Comp. to α Canis Maj	.....	9.0†	.....	6 40 45	−16 35	1.31	203.8	Au.	β 3596
136	Lal. 13284	− 5 1844	6.9	K9	6 47 26	− 5 3	0.57	270.0	Po.	
137	A. G. Bonn 5621	+40 1758	8.3	.....	6 49 30	+40 13	0.57	155.7	Bn.	
138	Lac. 2501	−28 1525	7.2	F	6 49 35	−28 24	0.58	145.5	Po.	
139	W.B. 6^h1500	+ 1 1600	8.0	G3	6 51 24	+ 1 18	0.57	109.9	Po.	
140	Lal. 13427	+48 1469	8.2	K1	6 54 0	+48 32	0.71	124.1	Po.	
141	Lal. 13576	+29 1441	6.3	F9	6 57 9	+29 30	0.82	168.0	Po.	
142	Lal. 13849	+21 1528	7.0	G6	7 4 11	+21 25	0.52	196.7	Po.	
143	Cp. St. St. 2483	−49 1163	7.6	.....	7 8 53	−49 17	0.77	359.3	Cape	
144	Lal. 14146	−12 1871	7.3	F9	7 11 16	−12 53	0.55	283.8	Po.	
145	Lac. 2740	−46 1360	7.5	.....	7 14 37	−46 49	0.60	342.5	Po.	
146	α Canis Minoris	+ 5 1739	1.0	F5	7 34 4	+ 5 29	1.25	215.0	Au.	β 4187
147	Comp. to α Canis Min	.....	13.0†	.....	7 34 4	+ 5 29	1.25	215.0	Au.	β 4187
148	W.B. 7^h1029	+39 1998	6.8	.....	7 38 9	+39 49	0.52	174.8	Rist.	
149	β Geminorum	+28 1463	1.3	K	7 39 12	+28 16	0.63	265.5	Au.	
150	Groom. 1339	+80 238	6.5	G6	7 39 45	+80 31	0.50	272.3	Po.	
151	T Puppis	−44 1829	6.6	F8	7 39 52	−44 55	0.55	183.1	Po.	
152	Lac. 2957	−33 1748	7.1	.....	7 41 51	−33 59	1.68	351.1	Po.	
153	Lal. 15290	+31 1684	8.2	F7	7 47 10	+30 55	1.97	158.3	Po.	
154	Lal. 15394	+19 1869	8.2	.....	7 49 5	+19 31	0.50	170.4	β	
155	Lal. 15547	+21 1731	8.5	.....	7 53 41	+21 8	0.59	159.1	Po.	
156	A.Oe. 7734	−25 3148	9.0	.....	7 53 50	−25 21	0.52	122.5	Po.	
157	Lal. 15505	+29 1664	7.5	G7	7 54 21	+29 31	1.19	186.8	Po.	
158	Lac. 3122	−59 944	6.6	F2	7 55 56	−60 2	0.56	77.7	Po.	
159	Fed. 1221	+72 395	8.0	.....	7 57 13	+72 13	0.50	333.7	Greenwich	
160	Lac. 3152	−29 2316	7.8	.....	8 2 55	−29 6	0.56	141.0	St.	
161	Lal. 15950	+32 1695	6.7	G2	8 5 23	+32 46	0.82	213.5	Po.	

† Magnitude uncertain.

162	Fed. 1266	+73°	407	8.5	.....	8h 8m47s	+73°44′	0″.58	330°.7	Greenwich	
163	W.B. 8h224	−11	2296	9.3	.....	8 11 32	−11 27	0.72	59.0	Rist.	
164	W.B. 8h181	+31	1781	8.3	K5	8 12 0	+30 56	0.90	200.3	Po.	
165	Lal. 16304	−12	2449	6.3	G9	8 13 39	−12 18	1.03	166.5	Po.	
166	A.Oe. 8869	+66	550	8.8	.....	8 16 21	+66 48	0.52	1.0	Greenwich	
167	A. G. Cambridge 3181	+54	1244	8.6	.....	8 28 12	+54 4	0.93	92.6	Cambridge	
168	W.B. 8h596	+42	1899	8.5	.....	8 28 48	+42 6	0.76	202.1	Rist.	
169	Lac. 3386	−31	2448	7.6	G2	8 28 57	−31 11	1.32	301.4	Po.	
170	Lal. 17046	+12	1888	8.1	.....	8 34 23	+11 53	0.52	194.6	Po.	
171	Lal. 17161	+42	1922	8.2	Kc	8 38 35	+42 3	0.69	204.0	Po.	
172	Fed. 1384[1]	+71	482	8.5	Ma	8 45 59	+71 11	1.40	255.6	Po.	β 4815
173	Fed. 1384[2]	.....		8.6	.....	8 45 59	+71 11	1.38	256.9	β	
174	ρ[1] Cancri	+28	1660	6.0	Ko	8 46 39	+28 43	0.55	243.9	Po.	
175	ι Ursae Majoris	+48	1707	3.1	A5	8 52 22	+48 26	0.51	240.4	Au.	
176	Comp. B. to ι Ursae Maj.	.....		9.5	.....	8 52 22	+48 26	0.51	240.4	β	β 4866
177	Comp. C. to ι Ursae Maj.	.....		9.8	.....	8 52 22	+48 26	0.51	240.4	β	
178	Lal. 17697	+42	1956	4.1	F5	8 54 9	+42 11	0.52	240.0	Ps.	
179	C. du C. +26° 25798	.....		11.2	.....	8 59 53	+25 42	0.50	229.8	Turner	
180	Lal. 18067	−14	2757	7.2	.....	9 3 46	−14 44	0.54	244.8	Po.	
181	Lal. 18137	+15	2003	7.0	G	9 6 49	+15 24	0.60	294.5	Po.	
182	Lal. 18115[1]	+53	1320	8.0	K8	9 7 35	+53 7	1.69	248.5	Po.	β 4972
183	Lal. 18115[2]	+53	1321	8.0	K8	9 7 36	+53 7	1.69	248.5	Po.	
184	Lal. 18286	+29	1883	7.0	K3	9 11 57	+29 0	0.52	173.4	Po.	
185	Lal. 18397	+40	2197	7.5	K7p	9 16 8	+40 38	0.55	223.5	Po.	Sp. Bin.
186	Lal. 18672	+ 6	2182	7.7	.....	9 24 43	+ 6 5	0.54	282.3	Po.	
187	θ Ursae Majoris	+52	1401	3.0	F8	9 26 10	+52 8	1.11	239.7	Au.	Sp. Bin.
188	Comp. to θ Ursae Maj.	.....		13.7	.....	9 26 10	+52 8	1.11	239.7	β	β 5123
189	Lal. 18812	+36	1979	5.5	G7	9 29 40	+36 16	0.77	249.4	Po.	
190	Lal. 19022	+43	1953	8.0	K5	9 37 7	+43 10	0.80	180.0	Po.	
191	Lal. 19229	+14	2151	8.2	A3p	9 43 28	+14 14	0.83	156.6	Po.	
192	W.B. 9h954	−11	2741	9.3	.....	9 46 10	−11 49	1.95	140.2	Po.	
193	Groom. 1596	+56	1421	8.2	G6	9 54 53	+56 5	0.49	205.0	Po.	
194	Lal. 19545	+32	1964	5.8	G1	9 55 15	+32 25	0.69	230.3	Ps.	
195	Groom. 1618	+50	1725	6.8	K7	10 5 15	+49 58	1.45	248.9	Po.	
196	A. G. Cambridge 3591	+51	1585	6.5	.....	10 7 21	+50 59	0.89	271.2	Cambridge	

TABLE I—*Continued*

No.	Name	*B.D.* or *C.P.D.*	Mag.	Spec.	α 1900	δ 1900	μ	φ	Authority	Remarks
197	A.Oe. 10640	+53° 1395	9.2	.....	$10^h\ 7^m28^s$	+53° 1′	0″.70	174°.3	Rist.	
198	W.B. 10^h234	+20 2465	9.2	.....	10 14 11	+20 22	0.51	270.0	Po.	
199	Munich II 5178	− 0 2326	8.8	.....	10 15 42	− 0 58	0.70	255.1	Nicolajew	
200	Groom. 1646	+49 1961	6.2	F9	10 21 54	+49 19	0.90	173.0	Po.	
201	W.B. 10^h366	− 5 3071	8.0	.....	10 23 13	− 6 5	0.50	232.2	Po.	
202	W.B. 10^h520	−11 2918	5.7	F1	10 31 34	−11 42	0.74	156.9	Po.	
203	Lal. 20881	+21 2247	7.9	.....	10 46 7	+20 49	0.50	210.2	Po.	
204	Lal. 21008	+28 1952	8.3	.....	10 50 52	+28 17	0.50	254.8	Po.	
205	A. G. Berlin C 1500	+70 639	9.5	.....	10 50 59	+70 8	0.66	270.0	Berlin C.	
206	Lal. 21120	−17 3273	4.0	K	10 54 54	−17 46	0.50	286.3	Ps.	
207	Lal. 21185	+36 2147	7.3	Ma	10 57 53	+36 38	4.77	186.4	Po.	
208	Lal. 21258	+44 2051	8.5	Ma	11 0 31	+44 2	4.47	282.8	Po.	
209	Lac. 4606	−29 3437	7.6	G	11 3 9	−29 38	0.51	252.1	Po.	
210	Comp. to Lal. 21308	.....	9.5	.....	11 5 32	+31 0	0.58	110.3	Po.	β 5695
211	Lal. 21368	+31 2240	8.5	.....	11 5 35	+31 0	0.58	110.3	Po.	
212	Anonymous	.....	9.5*	.....	11 5 54	+ 6 59	0.97	226.4	Wolf	
213	A. G. Washington 4420	−14 3277	9.0	.....	11 6 28	−14 26	0.90	130.7	Washington	
214	A. G. Nicolajew 3220	− 1 2505	9.4	.....	11 12 11	− 1 26	0.62	268.3	Nicolajew	
215	Lal. 21554	+32 2132	3.7	G	11 12 51	+32 6	0.74	219.5	Au.	Sp. Bin.
216	Comp. to Lal. 21554	.....	4.6	G	11 12 51	+32 6	0.74	219.5	Au.	β 5734
217	Lal. 21565	− 4 3049	7.2	G6	11 13 12	− 4 31	0.79	100.9	Po.	
218	A.Oe. 11677	+66 717	9.0	.....	11 14 50	+66 23	3.03	274.5	Po.	
219	83^1 Leonis	+ 3 2502	7.5	G8	11 21 42	+ 3 33	0.75	283.1	Po.	β 5779
220	83^2 Leonis	+ 3 2503	8.0	K8	11 21 43	+ 3 33	0.68	283.8	Ps.	
221	Anonymous	.....	9.7	.....	11 23 20	+ 8 6	1.23	190.4	β	
222	Br. 1584	−32 3122	6.7	G	11 29 38	−32 18	1.08	321.0	Po.	
223	Lal. 22069^2	.....	8.6	.....	11 33 28	+45 40	0.63	272.7	Po.	β 5858
224	Lal. 22069^1	+45 1947	6.5	F9	11 33 29	+45 40	0.63	272.7	Po.	
225	Cp. St. St. 4223	−43 5524	8.3	.....	11 36 14	−43 51	0.72	284.8	Cape	
226	A. G. Chris. 1806	+68 658	8.8	.....	11 36 48	+68 44	0.67	270.0	Schulhof†	

† Schulhof marks the P.M. as uncertain, *loc. cit.*

227	Groom. 1822	+48°	1964	7.8	Go	11h40m18s	+48°14′	0″.66	245°.0	Po.	
228	Lac. 4887	−39	5265	5.8	G	11 41 45	−39 57	1.58	284.3	Po.	
229	β Leonis	+15	2383	2.0	A2	11 43 58	+15 8	0.53	259.1	Au.	
230	β Virginis	+ 2	2489	3.3	F8	11 45 29	+ 2 20	0.77	109.9	Au.	
231	Groom. 1830	+38	2285	6.5	G5	11 47 13	+38 26	7.06	145.3	Po.	
232	W.B. 11h920	+20	2658	8.2	.....	11 49 27	+19 58	0.50	272.3	Berlin B	β 5960
233	W.B. 11h921	+20	2659	8.2	.....	11 49 30	+19 59	0.50	272.3	β	
234	Lac. 4955	−26	4626	7.5	.....	11 52 59	−27 8	1.21	234.8	Po.	
235	Lal. 22585	− 9	3413	6.4	G6	11 55 36	− 9 53	0.50	175.4	Po.	
236	Lal. 22632	+43	2182	6.7	G6	11 57 25	+43 39	0.67	213.5	Po.	
237	Lal. 22667	+ 4	2568	9.0	.....	11 58 58	+ 3 55	0.55	173.8	Po.	
238	Lal. 22701	− 0	2532	8.4	.....	12 0 9	− 0 57	0.51	270.0	Po.	
239	W.B. 12h69	− 2	3481	7.3	G4	12 7 25	− 2 32	0.73	304.4	Po.	
240	Lal. 22901	+10	2391	8.1	.....	12 7 50	+10 36	0.52	35.0	Ps.	
241	Lal. 22908	+11	2439	8.0	G3	12 8 7	+11 24	0.59	177.1	Po.	
242	Lal. 22954	− 9	3468	6.2	F6	12 10 2	− 9 44	1.03	176.1	Po.	
243	B.D. +29° 2279	+29	2279	9.5	.....	12 14 28	+28 56	0.66	291.7	Wolf	
244	W.B. 12h309	+42	2296	8.8	.....	12 16 56	+42 42	0.65	149.8	Rist.	
245	Anonymous	.....	.....	10.7	.....	12 17 25	+25 44	0.79	293.0	Wolf	
246	Lac. 5123	−66	1752	7.6	K	12 17 51	−67 5	0.82	281.3	Po.	
247	A.Oe. 12584	+74	493	8.0	.....	12 17 54	+73 48	0.50	248.4	Greenwich	
248	A. G. Lund 5422	+39	2519	7.5	.....	12 19 55	+38 52	0.61	272.9	Lund	
249	Lal. 23243	+32	2244	8.9	.....	12 20 22	+32 25	0.50	239.2	Po.	
250	Cp. St. St. 4496	−48	4799	7.6	G	12 21 31	−48 21	0.63	261.7	Cape	
251	Lal. 23361	− 2	3528	8.5	.....	12 24 37	− 2 46	0.69	205.8	Po.	
252	Lal. 23498	+42	2321	4.5	G	12 29 0	+41 54	0.78	291.8	Ps.	
253	Gi.Z. 8755	−77	359	9.3	.....	12 33 33	−77 18	0.83	294.0	Rist.	
254	γ Virginis1	− 0	2601	2.8	F	12 36 36	− 0 54	0.57	272.0	Ps.	β 6243
255	γ Virginis2	.....	.....	2.8	F	12 36 36	− 0 54	0.57	272.0	Ps.	
256	C.P.D. −37° 5339	−37	5339	7.9	.....	12 38 24	−37 9	0.69	250.9	Kapteyn	
257	Lal. 23808	+10	2468	6.4	K1	12 41 18	+10 6	0.52	149.0	Ps.	
258	Lal. 23917	+ 2	2585	8.2	.....	12 44 39	+ 1 45	0.68	182.5	Po.	
259	Lal. 23995	−17	3723	8.2	.....	12 47 56	−17 57	0.89	159.5	Po.	
260	δ Virginis	+ 4	2669	3.0	Ma	12 50 34	+ 3 56	0.50	264.3	Po.	
261	Lal. 24168	− 9	3595	7.7	G9	12 53 54	− 9 18	0.82	282.0	Po.	

TABLE I—*Continued*

No.	Name	*B.D.* or *C.P.D.*	Mag.	Spec.	α 1900	δ 1900	μ	φ	Authority	Remarks
262	A. G. Nicolajew 3508	− 1° 2754	9.1	.....	12h55m14s	− 2° 10′	0″.90	270°.6	Nicolajew	
263	A.Oe. 12585	−26 4871	7.9	.....	12 56 5	−26 50	0.54	240.1	Po.	
264	W.B. 12h920	− 7 3525	8.5	.....	12 56 10	− 7 54	0.54	256.0	Po.	
265	Cp. St. St. 4746	−40 6050	9.2	.....	13 2 58	−41 6	0.69	268.1	Cape	
266	Lal. 24414	+ 6 2697	6.8	G3	13 3 47	+ 5 46	0.72	175.2	Po.	
267	A. G. Washington 5002	−15 3605	9.1	.....	13 3 50	−16 13	0.50	180.0	Washington	Only μ δ
268	Lal. 24504	+10 2519	8.5	.....	13 6 25	+10 9	0.54	297.5	Po.	
269	A.Oe. 13407	+68 714	8.5	.....	13 7 2	+68 2	0.74	272.0	Greenwich	
270	Lal. 24522	+28 2193	5.0	G	13 7 12	+28 23	1.20	318.7	Po.	
271	A. G. Berlin A 4855	+18 2700	7.8	.....	13 7 31	+18 3	0.60	273.4	Berlin A	
272	Lal. 24652	+17 2611	7.0	.....	13 11 52	+17 35	0.70	113.6	Krüger	β 6442
273	Comp. to Lal. 24652	.....	10.1	.....	13 11 52	+17 35	0.70	113.6	Krüger	β 6442
274	Lal. 24680	−17 3813	5.0	K	13 13 10	−17 45	1.51	225.5	Po.	
275	W.B. 13h241	+35 2436	9.0	.....	13 14 55	+35 39	0.92	154.3	Po.	β 6452
276	Comp. to W.B. 13h241	.....	11.5	.....	13 14 56	+35 39	0.92	154.3	β	β 6452
277	W.B. 13h216	+ 4 2729	8.5	.....	13 15 43	+ 4 39	0.58	292.2	Po.	
278	Anonymous	.....	11.0*	.....	13 18 31	−13 31	0.61	232.8	Wolf	
279	Lal. 24838	+29 2405	8.6	.....	13 18 55	+29 45	0.54	299.1	Po.	
280	Lal. 24915	− 0 2691	8.0	.....	13 23 9	− 0 19	0.50	149.3	Nicolajew	
281	Lal. 24926	+14 2621	5.5	F	13 23 32	+14 19	0.64	204.2	Po.	
282	B.D. −7° 3632	− 7 3632	9.5	.....	13 25 7	− 8 3	1.20	250.7	Wolf	
283	Lal. 25012	− 1 2832	7.5	G6	13 26 36	− 1 49	0.91	284.7	Po.	
284	ι Centauri	−32 3479	4.9	F5	13 40 0	−32 32	0.51	251.6	Po.	
285	A. G. Berlin A 4999	+18 2776	9.2	.....	13 40 13	+18 21	1.92	169.6	Berlin A	
286	Lal. 25372	+15 2620	8.5	Ma5	13 40 40	+15 26	2.32	129.2	Po.	
287	Lal. 25404	+ 7 2690	6.5	F5	13 42 0	+ 6 51	0.50	254.8	Po.	
288	Lal. 25426	+18 2782	4.6	F5	13 42 31	+17 57	0.50	274.7	Po.	
289	Lal. 25484	−23 5802	6.8	F8	13 45 50	−23 53	0.68	238.9	Po.	
290	Cp. St. St. 5010	−50 6387	7.8	.....	13 46 20	−50 26	0.65	266.8	Cape	
291	C. du C. +25° 86067	.....	10.4*	.....	13 54 49	+25 44	0.54	262.4	Bellamy	
292	θ Centauri	−35 6109	3.4	K	14 0 48	−35 53	0.78	225.0	Po.	

293	α Boötis	+19° 2777	1.0	K	14h 11m 6s	+19° 42′	2″.28	209°.6	Au.	
294	C.P.D. −58° 5467	−58 5467	8.0	.....	14 12 0	−58 54	0.93	214.5	Kapteyn	
295	Lal. 26196	− 4 3665	7.6	K1	14 14 25	− 4 41	0.65	259.4	Po.	
296	Lal. 26294	+30 2512	8.3	.....	14 17 40	+30 6	0.56	296.3	Ps.	
297	Lal. 26289	+ 1 2920	6.5	Go	14 18 8	+ 1 43	0.55	156.3	Po.	
298	A. G. Berlin B 5072	+24 2733	9.0	.....	14 21 5	+24 6	1.38	143.5	Po.	β 6869
299	A. G. Berlin B 5073	.....	9.0	.....	14 21 9	+24 6	1.38	143.5	Po.	β 6869
300	C. du C. +25° 42937	+24 2735	9.5	.....	14 23 17	+24 17	0.50	273.1	Bellamy	
301	B.D. −7° 3856	− 7 3856	9.0	.....	14 25 38	− 8 12	1.23	260.0	Hayden	
302	B.D. +10° 2703	+10 2703	8.4	.....	14 28 40	+ 9 47	0.53	162.1	Po.	
303	A. G. Leiden 5231	+34 2541	9.0	.....	14 30 54	+34 10	0.74	342.7	Kapteyn	
304	Lal. 26630	−11 3770	6.0	F5	14 31 40	−11 53	0.96	292.0	Po.	
305	α² Centauri	−60 5483	2.1	G	14 32 48	−60 25	3.68	281.9	Po.	
306	α¹ Centauri	.....	3.0*	K5	14 32 49	−60 25	3.68	281.9	St.	
307	W.B. 14h847	+17 2785	8.8	.....	14 41 43	+16 56	0.94	185.4	Kobold	
308	W.B. 14h810	+ 7 2850	9.1	.....	14 45 29	+ 7 14	0.62	263.6	Po.	
309	Lal. 27026	−23 5999	8.0	.....	14 46 0	−23 53	1.02	241.9	Po.	
310	Lal. 27137	+19 2881	6.3	K	14 48 51	+19 33	0.53	242.4	Ps.	
311	Lal. 27155	+23 2751	8.5	.....	14 49 20	+23 45	0.75	275.0	Ps.	
312	Yarnall 6246	−20 4123	8.7	.....	14 51 36	−20 58	2.01	151.4	Gr.	β 7060
313	Lal. 27173	−20 4125	6.0	K6	14 51 37	−20 58	2.06	150.7	Po.	β 7060
314	Lal. 27298	+54 1716	7.7	Ko	14 52 21	+54 4	1.08	296.3	Po.	
315	Lal. 27274	−21 4009	8.3	.....	14 54 9	−21 36	0.80	227.6	Po.	
316	W.B. 14h989	−10 4011	9.3	.....	14 55 18	−10 44	0.54	180.0	Po.	
317	Cp. St. St. 5447	−48 7086	8.7	.....	14 59 14	−48 53	0.55	186.7	Cape	
318	Lal. 27531	− 7 3963	8.0	.....	15 2 53	− 7 31	0.50	198.8	Po.	
319	Lal. 27558	+ 9 3001	8.7	.....	15 2 58	+ 9 16	0.54	258.2	Ps.	
320	B.D. +25° 2874	+25 2874	9.2	.....	15 3 8	+25 18	0.92	298.5	Po.	
321	A.Oe. 14318	−15 4041	9.2	.....	15 4 44	−15 59	3.76	194.8	Po.	
322	A.Oe. 14320	−15 4042	9.0	Go	15 4 45	−15 54	3.75	194.7	Po.	
323	Lal. 27742	+19 2939	6.7	G4	15 8 15	+19 39	0.68	296.2	Po.	β 7162
324	Lal. 27743	.....	7.6	G6	15 8 15	+19 40	0.62	295.3	Ps.	β 7162
325	Lal. 27744	− 0 2944	7.0	G7	15 8 50	− 0 58	1.38	247.4	Po.	
326	Lal. 27917	+ 2 2944	5.0	G	15 14 12	+ 2 9	0.65	146.3	Ps.	β 7213
327	Comp. to Lal. 27917	.....	10.0	.....	15 14 12	+ 2 9	0.65	146.3	β	β 7213

TABLE I—*Continued*

No.	Name	*B.D.* or *C.P.D.*	Mag.	Spec.	α 1900	δ 1900	μ	φ	Authority	Remarks
328	Lal. 27958	+26° 2677	8.0	G2	15h14m45s	+26° 4′	0″.51	257°.6	Po.	
329	Cp. St. St. 5545	−47 7075	7.2	G	15 15 4	−47 57	1.67	260.8	Cape	
330	Comp. to A. G. Leiden 5456	.....	9.4	.....	15 16 5	+31 3	1.04	113.6	Wilkens	β 7226
331	A. G. Leiden 5456	+31 2722	9.2	.....	15 16 6	+31 3	1.04	113.6	Wilkens	β 7226
332	W.B. 15h268	+ 1 3071	8.7	.....	15 17 40	+ 1 47	0.52	230.5	Po.	
333	W.B. 15h716	+40 2903	7.8	K6	15 32 23	+40 10	0.50	278.1	β	
334	W.B. 15h720	+40 2905	6.8	K1	15 32 29	+40 8	0.50	278.1	Po.	β 7332
335	Comp. to W.B. 15h720	.....	7.1	.....	15 32 29	+40 8	0.50	278.1	Po.	β 7332
336	Lal. 28607	−10 4149	7.0	A2p	15 37 42	−10 36	1.18	253.3	Po.	
337	Lac. 6521	−37 6571	6.9	G	15 40 59	−37 36	0.59	240.4	Po.	
338	Lal. 28935	+13 3024	6.3	G	15 48 33	+13 31	0.61	197.2	Po.	
339	Lal. 28992	+42 2648	4.3	F	15 49 13	+42 44	0.75	35.2	Po.	
340	Cp. St. St. 5767	−47 7499	9.0	.....	15 50 15	−47 21	0.86	262.9	Cape	
341	γ Serpentis	+16 2849	3.8	F8	15 51 50	+15 59	1.32	168.2	Au.	
342	W.B. 15h1323	+28 2503	8.0	.....	15 54 32	+28 1	0.85	291.5	Bur. des Long. 1913	
343	Lal. 29085	−16 4196	6.2	F	15 54 43	−16 14	0.77	239.4	Po.	
344	Lal. 29213	+33 2663	5.7	F	15 57 13	+33 36	0.81	194.2	Po.	
345	Lal. 29307	+25 3020	7.5	.....	15 59 56	+25 31	0.87	211.1	Ps.	
346	Lal. 29330	+11 2910	8.5	.....	16 1 12	+10 57	0.50	256.2	Po.	
347	Lal. 29381	+39 2947	6.5	G5	16 1 30	+39 26	0.55	275.2	Po.	
348	Lal. 29439	+39 2950	8.4	.....	16 2 54	+38 55	0.60	159.4	Po.	
349	Lal. 29437	+ 6 3169	6.5	K1	16 4 16	+ 6 40	0.79	162.3	Po.	
350	Lal. 29617	− 7 4242	5.9	G1	16 10 11	− 8 6	0.55	157.7	Po.	
351	Lal. 29917	+07 935	8.6	.....	16 16 32	+07 29	0.50	281.9	Po.	
352	Comp. to Lal. 29917	.....	10.6	.....	16 16 34	+07 30	0.50	281.9	β	
353	Anonymous	.....	10.7*	.....	16 21 7	+48 36	1.24	111.4	Kapteyn	
354	W.B. 16h400	+ 3 3203	8.9	.....	16 23 36	+ 3 29	0 51	180.0	Po.	
355	Lal. 30024[1]	+18 3182	7.0	K1	16 24 29	+18 37	0.53	319.7	Po.	β 7642
356	Lal. 30024[2]	.....	7.0	.....	16 24 29	+18 37	0.53	319.7	β	β 7642
357	Cp. St. St. 5969	−40 7356	9.5	.....	16 25 32	−40 6	1.06	317.1	Cape	

358	Lal. 30044	+ 4° 3195	7.6	F6	16h 25m 33s	+ 4° 26′	1″.46	197°.9	Po.	
359	Lal. 30191	− 1 3220	5.8	F	16 31 6	− 2 7	0.55	126.1	Boss	
360	Lal. 30271	+31 2873	7.2	F2	16 32 34	+31 9	0.49	177.2	Po.	
361	W.B. 16h964	+31 2875	9.1	.....	16 32 55	+31 19	0.60	141.0	Rist.	
362	Lal. 30433	+31 2884	3.0	G	16 37 31	+31 47	0.62	311.7	Au.	Sp. Bin.
363	Comp. to Lal. 30433	.....	6.5	.....	16 37 31	+31 47	0.62	311.7	Au.	β 7717
364	A. G. Chris. 2517	+66 969	9.0	.....	16 38 44	+66 7	0.64	269.7	Schulhof†	
365	Lal. 30699	+68 883	7.6	G7	16 42 51	+68 16	0.52	235.3	Greenwich	
366	ε Scorpii	−34 6635	5.0	K	16 43 41	−34 7	0.68	245.7	Po.	
367	Lal. 30694	+ 0 3593	7.0	G6	16 47 56	+ 0 11	1.66	206.1	Po.	
368	W.B. 16h906	− 8 4352	8.8	Mb	16 50 8	− 8 9	1.27	226.8	Po.	
369	C. du C. +25° 48511	+25 3173	9.4	.....	16 54 4	+25 55	0.52	188.0	Bellamy	
370	Lal. 31132	+47 2420	6.6	G5	16 59 47	+47 12	0.83	9.0	Po.	
371	Lal. 31055	− 4 4225	7.5	K5	16 59 51	− 4 54	1.48	218.9	Po.	
372	C.P.D. −75° 1368	−75 1368	8.0	.....	17 9 0	−75 14	1.03	265.3	Kapteyn	
373	Lal. 31311[1]	−26 5858	5.5	K	17 9 12	−26 27	1.29	203.8	Po.	β 7905
374	Lal. 31311[2]	.....	5.5	K	17 9 12	−26 27	1.29	203.8	β	
375	B.D. +42° 2810	+42 2810	9.4	.....	17 10 0	+42 28	1.11	250.5	Kostinsky	
376	Br. 2179	−26 5863	8.0	K3	17 10 4	−26 24	1.25	204.1	Po.	
377	Cp. St. St. 6241	−46 8513	7.3	K	17 11 28	−46 32	0.95	72.1	Cape	
378	Lac. 7215	−34 6803	7.2	K5	17 12 9	−34 53	1.20	100.1	Po.	
379	Lal. 31618	+32 2896	5.7	G0	17 16 55	+32 36	1.06	172.9	Po.	
380	Cp. St. St. 6277	−41 7979	8.2	.....	17 17 47	−41 24	0.58	82.9	Cape	
381	W.B. 17h322	+ 2 3312	8.0	K9	17 20 47	+ 2 14	1.36	206.2	Po.	
382	A. G. Leiden 6197	+31 3025	9.1	.....	17 22 57	+31 8	0.52	285.6	Wilkens	
383	Lal. 32047	+67 1014	6.5	K1	17 25 19	+67 23	0.52	273.3	Po.	
384	A. G. Chris. 2661	+68 930	8.8	.....	17 26 14	+68 27	0.80	88.0	Schulhof†	
385	W.B. 17h514	+ 6 3455	8.5	F1	17 29 53	+ 6 4	0.58	308.7	Po.	
386	Anonymous	.....	9.1*	.....	17 33 27	+18 37	1.29	40.0	Slocum	
387	Lal. 32324	+61 1678	6.0	F	17 33 57	+61 57	0.56	153.4	Po.	β 8099
388	Comp. to Lal. 32324	.....	10.6	.....	17 33 57	+61 57	0.56	153.4	β	
389	B.D. +18° 3424	+18 3424	9.2	.....	17 34 20	+18 37	1.20	311.6	Berlin A‡	
390	A. G. Chris. 2703	+68 941	8.3	.....	17 35 47	+68 52	0.83	279.2	Schulhof	

† Schulhof marks the P.M. as uncertain, *loc. cit.*

‡ Berlin A has a small weight for the P.M. of this star. Slocum gives $\mu = 0''.09$, $p = 144°.7$, *Astrophysical Journal*, **38**, 15, 1913

TABLE I—*Continued*

No.	Name	*B.D.* or *C.P.D.*	Mag.	Spec.	α 1900	δ 1900	μ	φ	Authority	Remarks
391	Lal. 32322	+37° 2926	8.4	.....	17h 36m 15s	+37° 16′	0″.88	204°.2	Ps.	
392	A.Oe. 17415	+68 946	9.1	Mb	17 37 0	+68 26	1.30	196.5	Po.	
393	Lal. 32390	+21 3198	7.5	.....	17 39 2	+21 40	0.61	175.3	Ps.	
394	Comp. B. to Lal. 32519	.....	10.5	.....	17 42 31	+27 47	0.81	203.4	β	} β 8162
395	Comp. C. to Lal. 32519	.....	11.0	Ma	17 42 31	+27 47	0.81	203.4	β	
396	Lal. 32519	+27 2888	3.5	G5	17 42 33	+27 47	0.81	203.4	Po.	
397	B.D. +26° 3151	+26 3151	7.3	.....	17 58 26	+26 20	0.66	148.0	Po.	
398	Lal. 33169	+ 2 3482	4.0	K	18 0 24	+ 2 31	1.15	167.4	Po.	} Sp. Bin.
399	Comp. to Lal. 33169	.....	6.0	.....	18 0 24	+ 2 31	1.15	167.4	Po.	} β 8340
400	A. G. Washington 6520	−16 4706	9.1	.....	18 0 31	−16 42	0.55	90.0	Washington	Only μ α
401	Lal. 33439	+38 3095	6.7	K2	18 6 19	+38 27	0.62	217.5	Rist.	
402	Lal. 33802	− 2 4599	3	K	18 16 8	− 2 55	0.91	221.4	Au.	
403	B.D. +8° 3689	+ 8 3689	8.0	G1	18 21 25	+ 8 44	0.49	200.4	Kapteyn	
404	B.D. +8° 3692	+ 8 3692	8.5	G5	18 21 37	+ 8 34	0.50	202.7	Kapteyn	
405	Lal. 34392	+72 839	3.8	F8	18 22 52	+72 41	0.63	125.9	Au.	
406	A. G. Leiden 6797	+31 3330	8.7	.....	18 37 7	+31 28	0.82	174.8	Wilkens	
407	Pos. Med. 2164[1]	+59 1915	8.9	Mb	18 41 40	+59 29	2.28	325.0	Po.	} β 8798
408	Pos. Med. 2164[2]	.....	9.4	Ma	18 41 41	+59 28	2.28	325.0	Po.	
409	Lal. 34986	+10 3665	8.1	K5	18 43 46	+10 39	0.51	168.3	Comstock	
410	W.B. 18h 1295	+17 3729	9.0	.....	18 44 29	+17 20	0.60	221.5	Po.	
411	Munich I 18180	+ 5 3993	9.3	Ma	18 53 7	+ 5 48	1.24	191.1	Po.	
412	A. G. Berlin A 7153	+18 3911	9.5	.....	18 56 23	+18 57	0.58	209.7	Berlin A	
413	L.Bo. 2844	−20 5385	9.0	.....	18 58 3	−20 35	0.72	204.6	Rist.	
414	Munich I 18816	+ 7 3967	9.2	K5:	19 2 14	+ 7 29	0.80	199.8	Po.	
415	Comp. C. to 17 Lyrae	.....	11.3*	Ma	19 3 40	+32 21	1.75	49.5	β	
416	A.Oe. 19156	−21 5273	8.5	.....	19 3 43	−21 37	0.50	205.0	Po.	
417	B.D. −0° 3676	− 0 3676	9.1	.....	19 8 14	− 0 45	0.62	217.2	Roy	
418	Lal. 36245	+49 2959	6.2	G3	19 9 30	+49 40	0.62	348.0	Po.	} β 9137
419	Lal. 36249	.....	6.7	G2	19 9 31	+49 40	0.62	348.0	Po.	
420	Lal. 36647	+11 3833	5.5	G7	19 20 12	+11 44	0.96	48.8	Au.	
421	Lal. 36717	+24 3737	6.1	F4	19 21 17	+24 44	0.66	197.6	Au.	

422	Lal. 36872	−28°	6957	7.8	.....	19h 26m 26s	−28° 13′	0″.76	177°.7	Po.	
423	Groom. 2875	+58	1929	6.4	K1	19 29 28	+58 23	0.66	232.6	Po.	
424	Lal. 37120	+32	3474	7.0	G2	19 29 44	+32 59	0.52	296.1	Po.	
425	σ Draconis	+69	1053	5.0	G5	19 32 33	+69 29	1.83	163.8	Po.	
426	α Aquilae	+ 8	4236	1.2	A5	19 45 54	+ 8 36	0.64	53.3	Au.	
427	Lal. 38100	−10	5238	6.3	F7	19 54 21	−10 13	0.51	217.1	Po.	
428	Lal. 38139	−12	5613	7.3	.....	19 55 30	−12 31	0.50	225.0	Po.	
429	Lac. 8267	−67	3703	7.1	G5	19 55 34	−67 35	1.25	122.3	Po.	
430	Lal. 38287	+15	4026	7.0	G6	19 58 0	+15 20	0.60	198.4	Po.	
431	δ Pavonis	−66	3474	4.3	G5	19 58 55	−66 26	1.65	135.5	Po.	
432	Lal. 38380	+29	3872	6.0	K0	19 59 31	+29 38	0.86	127.4	Po.	
433	15 Sagittae	+16	4121	5.5	G0	19 59 37	+16 48	0.58	223.6	Po.	
434	Lal. 38383	+22	3908	7.0	K1	19 59 41	+23 5	1.39	227.4	Po.	
435	b^1 Cygni	+35	3959	5.5	K	20 2 39	+35 42	0.50	207.8	Boss	
436	Lac. 8362	−36	9037	6.6	K5	20 4 38	−36 21	1.70	164.7	Po.	
437	Lal. 38683	+15	4074	7.0	G9	20 6 34	+15 53	0.55	310.6	Po.	
438	Cp. St. St. 7242	−45	9899	8.8	.....	20 6 45	−45 28	0.75	104.6	Cape	
439	Lal. 38711	−27	6972	7.2	G9	20 9 3	−27 20	1.28	100.8	Po.	
440	B.D. +76° 785	+76	785	9.0	.....	20 13 51	+76 55	0.53	168.3	Greenwich	
441	A. G. Cambridge 6486	.....	.....	7.4	.....	20 15 56	+55 5	0.81	270.0	Cambridge	β 10135
442	A. G. Cambridge 6487	+54	2329	6.0	A	20 15 57	+55 5	0.81	270.0	Cambridge	
443	Groom. 3150	+66	1281	6.2	F8	20 16 32	+66 32	0.57	57.2	Po.	
444	A.Oe. 20452	−21	5703	8.2	F5	20 17 42	−21 40	1.22	154.7	Po.	
445	Lal. 39704	+41	3799	6.7	G6	20 29 20	+41 33	0.50	337.9	Bonn	
446	B.D. +5° 4556	+ 5	4556	8.7	.....	20 30 13	+ 5 47	0.51	135.3	β	
447	Lac. 8490	−60	7419	6.5	F8	20 31 46	−60 53	0.56	150.2	St.	
448	W.B. $20^h 802$	+ 5	4570	9.0	.....	20 33 40	+ 5 18	0.90	261.6	Sj.	
449	Lal. 39816	−24	7050	6.9	G	20 34 15	−24 8	0.62	48.9	Po.	
450	Lal. 39866	+ 4	4510	8.4	K5	20 34 33	+ 4 37	0.85	86.6	Po.	
451	Lal. 39854	−19	5889	8.2	.....	20 35 6	−19 8	0.50	181.1	Po.	
452	Fed. 3562	+75	752	7.2	.....	20 38 42	+75 14	0.64	33.0	Po.	
453	ε Cygni	+33	4018	2.6	K	20 42 10	+33 36	0.51	48.4	β	Sp. Bin.
454	η Cephei	+61	2050	3.7	K0	20 43 15	+61 27	0.82	6.3	Au.	
455	Lac. 8620	−44	9918	6.8	G	20 51 3	−44 29	1.12	208.1	Po.	
456	B.D. +61° 2068	+61	2068	8.4	.....	20 51 16	+61 48	0.80	192.9	β	

TABLE I—*Continued*

No.	Name	*B.D.* or *C.P.D.*	Mag.	Spec.	α 1900	δ 1900	μ	φ	Authority	Remarks
457	Fed. 3638	+74° 889	7.8	G4	20h 52m 22s	+74° 23′	0″.70	38°.0	Po.	
458	W.Mu.Z. 53.22	−34 8843	8.4	.....	20 55 56	−34 27	1.31	172.6	Rist.	
459	Lac. 8625	−73 2192	6.6	F8	20 58 54	−73 34	0.60	129.6	Po.	
460	W.B. 20h1454	+ 2 4295	8.2	F3	20 59 6	+ 2 36	0.55	222.0	Po.	
461	Lal. 40844	+ 6 4741	8.8	K6	21 0 23	+ 6 41	0.57	177.0	Po.	
462	61¹ Cygni	+38 4343	5.0	K8	21 2 25	+38 15	5.18	51.4	Au.	β 10732
463	61² Cygni	+38 4344	5.3	K8	21 2 26	+38 15	5.12	53.7	Au.	β 10732
464	W.B. 21h97	+17 4519	7.3	F5	21 7 21	+17 21	0.91	188.2	Po.	
465	Fed. 3738	+73 925	8.6	.....	21 8 48	+73 18	0.52	222.0	Küstner	
466	Lac. 8733	−61 6537	7.4	.....	21 10 47	−61 46	0.67	130.7	Po.	
467	Lac. 8760	−39 8920	7.4	.....	21 11 24	−39 15	3.46	249.4	Po.	
468	Lal. 41348	− 0 4195	8.5	.....	21 12 52	− 0 15	0.50	112.4	β	
469	Lal. 41363	−26 7193	7.4	G5	21 13 59	−26 46	0.67	237.7	Po.	β 10881
470	Comp. to Lal. 41363	.....	9.9	.....	21 13 59	−26 46	0.67	237.7	Po.	β 10881
471	A.Oe. 21308	−20 6185	9.0	.....	21 14 36	−20 15	0.80	192.3	Po.	
472	γ Pavonis	−65 3918	4.1	F8	21 18 11	−65 49	0.80	5.7	Po.	
473	W.B. 21h502	−13 5945	9.1	.....	21 24 30	−12 56	1.06	105.3	Po.	
474	W.B. 21h594	+45 3561	7.5	.....	21 26 0	+45 27	0.51	46.0	Rist.	
475	Cp. St. St. 7704	−50 11576	8.0	.....	21 28 14	−50 14	0.62	259.8	Cape	
476	Lal. 42128	− 2 5588	8.7	.....	21 33 2	− 2 45	0.50	303.0	Bossert	
477	A. G. Berlin B 8366	+24 4460	8.8	.....	21 39 42	+24 53	0.68	213.3	Bellamy	
478	Lal. 42883	+29 4550	7.4	F7	21 54 15	+29 21	0.56	222.8	Po.	
479	ε Indi	−57 10015	6.7	K5	21 55 43	−57 12	4.71	123.9	Po.	
480	Lal. 43065	+ 4 4800	5.0	Kp	22 0 38	+ 4 34	0.50	263.6	Ps.†	
481	Lal. 43205	+52 3112	7.9	G8	22 3 5	+52 39	0.61	235.0	Po.	
482	W.B. 22h82	+22 4567	8.8	.....	22 5 55	+22 15	0.60	264.2	Po.	
483	Lac. 9061	−41 9759	6.4	G	22 8 32	−41 51	0.92	142.5	Po.	
484	Lac. 9076	−54 10055	6.2	G	22 11 42	−54 7	0.80	147.3	Po.	
485	Lal. 43492	+12 4797	7.0	F9	22 12 15	+12 24	0.84	83.9	Po.	
486	ν Indi	−72 2690	6.0	F	22 16 2	−72 45	1.45	120.6	Po.	

† The P.M. given in Paris IV seems well founded. Still Bossert gives $\mu = 0''.13$, $p = 34°.1$, Boss $\mu = 0''.14$, $p = 52°.0$.

487	Cp. St. St. 7975	−51° 11806	8.6	.....	22h 16m 17s	−51° 17′	1″.58	178°.9	Cape		
488	C.P.D. −30° 6641	−30 6641	7.9	.....	22 23 35	−30 30	0.83	163.7	Union Obs.		
489	Krüger 60	+56 2783	9.0	Mb	22 24 28	+57 12	0.94	245.2	β	}	β 11761
490	Comp. B. to Krüger 60	.....	12.0	.....	22 24 28	+57 12	0.94	245.2	β		
491	B.D. +53° 2911	+53 2911	9.5	.....	22 28 43	+53 16	1.23	83.1	Balanowsky		
492	Kli. 6256	+ 4 4879	8.3	.....	22 30 32	+ 4 52	0.54	140.0	Rist.		
493	Münich I 31343	+ 1 4037	9.4	.....	22 33 52	+ 2 0	0.55	99.5	Po.		
494	Lal. 44552	+11 4875	4.8	F5	22 41 42	+11 40	0.54	155.1	Po.	}	β 11957
495	Comp. to Lal. 44552	.....	12.8	.....	22 41 43	+11 40	0.54	155.1	β		
496	Cp. St. St. 8141	−42 9492	7.9	.....	22 44 29	−42 1	0.51	240.0	Cape		
497	Lal. 44739	+ 9 5122	5.0	F	22 47 20	+ 9 18	0.50	85.4	Po.		
498	Lal. 44964	−23 8259	8.1	.....	22 55 0	−23 4	0.92	270.4	Po.		
499	B.D. +68° 1345	+68 1345	8.3	.....	22 55 9	+68 29	0.63	118.1	Greenwich		
500	Lal. 45028	− 4 5804	7.8	K2	22 56 39	− 4 23	0.54	122.8	Po.		
501	Lac. 9352	−36 9694	8.2	K	22 59 25	−36 26	7.00	80.5	Po.		
502	Fed. 4371	+67 1498	7.5	G3	23 1 10	+67 52	0.60	75.5	Po.		
503	Lal. 45292	− 3 5577	8.2	K5:	23 3 58	− 2 48	0.59	102.6	Po.		
504	Lac. 9396	−63 4862	7.1	G	23 7 57	−63 14	0.63	129.2	Po.		
505	Br. 3077	+56 2966	6.0	K7	23 8 28	+56 37	2.08	82.3	Au.		
506	Lal. 45455	− 9 6149	8.2	Fo	23 8 52	− 9 28	0.56	98.3	Po.	}	β 12234
507	Lal. 45456	− 9 6150	9.0	.....	23 8 52	− 9 29	0.55	95.2	Po.		
508	W.B. 23h175	−14 6437	8.2	A2	23 11 54	−14 22	1.31	202.9	Po.		
509	Lal. 45565	+ 2 4648	3.8	K	23 11 59	+ 2 44	0.73	88.4	Au.		
510	Lal. 45638	+ 4 4994	8.5	G8	23 13 46	+ 4 52	0.52	103.6	Ps.	}	β 12290
511	Comp. to Lal. 45638	.....	9.4	.....	23 13 46	+ 4 52	0.52	103.6	β		
512	W.B. 23h257	+28 4562	8.5	.....	23 14 59	+28 19	0.57	94.0	Po.		
513	Lal. 45755	+43 4445	7.3	G8	23 16 46	+43 33	0.67	70.8	Po.		
514	A. G. Cambridge 8232	+52 3440	7.0	.....	23 20 57	+52 26	1.59	90.6	Cambridge		
515	A.Oe. 25685	+58 2005	7.5	K1	23 26 30	+58 37	1.08	85.2	Rist.		
516	d'Agelet 6348	+17 4946	8.0	.....	23 31 0	+17 53	0.68	73.8	Po.		
517	Lac. 9537	−73 2299	7.4	.....	23 33 42	−73 15	0.74	170.7	Po.		
518	Lal. 46351	+ 4 5035	4.2	F5	23 34 48	+ 5 5	0.56	141.5	Au.		
519	Lal. 46495	+57 2787	7.5	F8	23 38 32	+57 31	0.62	37.8	Po.		
520	W.B. 23h819	+28 4634	8.6	.....	23 40 0	+29 0	0.85	86.7	Po.		
521	Lac. 9585	−42 9607	7.3	.....	23 41 15	−42 7	0.86	172.6	Po.		

TABLE I—*Continued*

No.	Name	*B.D.* or *C.P.D.*	Mag.	Spec.	α 1900	δ 1900	μ	φ	Authority	Remarks
522	Cp. St. St. 8461	−48° 10958	7.4	.....	$23^h42^m\ 7^s$	−48° 50′	0″.50	242°.1	Cape	
523	Lal. 46650	+ 1 4774	8.7	Ma	23 43 59	+ 1 52	1.39	135.9	Po.	
524	Munich I 32805	+ 2 4723	8.3	G7	23 44 56	+ 2 19	0.50	62.8	Po.	
525	Lal. 46867	+27 4642	7.0	.....	23 49 55	+28 5	0.56	88.0	Po.	
526	Lal. 46972	+49 4291	6.7	.....	23 53 3	+49 53	0.61	293.7	Bonn†	
527	B.D. +45° 4378	+45 4378	9.2	.....	23 53 32	+46 10	0.53	93.4	Bonn	
528	A.Oe. 23166	−20 6684	7.3	.....	23 54 17	−20 35	0.63	116.6	Po.	
529	Lal. 47118	+26 4734	6.1	G	23 56 57	+26 33	1.29	140.1	Po.	} β 12701
530	Comp. to Lal. 47118	.....	12.6	.....	23 56 57	+26 33	1.29	140.1	β	
531	Gould 32416	−37 9435	8.8	.....	23 59 31	−37 51	6.29	114.2	Po.	
532	Lal. 47207	+33 4828	6.3	Go	23 59 39	+34 6	0.78	84.1	Po.	
533	Anonymous	.....	9.5*	.....	23 59 54	+45 14	0.86	100.0	Furuhjelm	

† Porter gives for this star $\mu = 0''.26$, $\phi = 349°.1$. *Cin. Publ.*, **13**, 1893.

After this paper had been sent to the printer, *Circular No. 19 of the Union Observatory* appeared with the list by Innes of proper motion stars south of −19°. The following numbers of Innes' list should be included here, although for some of the stars the proper motion needs confirmation:

1[a]	33	42	73	74	80	99	137	173
177	224	227	296	357	397	415	416	417
427	429	430	452	542[a]	548[a]	638	653	690
744	748							

MOUNT WILSON SOLAR OBSERVATORY
January 25, 1915

PHOTOGRAPHIC AND PHOTO-VISUAL MAGNITUDES OF STARS NEAR THE NORTH POLE[1]

By FREDERICK H. SEARES

I. INTRODUCTION

The results here presented summarize an extended investigation of the photographic and photo-visual magnitude scales with the 60-inch reflector, which is soon to be published in detail as Vol. 3 of *Papers from the Mount Wilson Solar Observatory*.[2]

The investigation was begun in 1910, but various difficulties encountered in devising satisfactory methods of observation and reduction had first to be overcome, and it was not until 1912 that preliminary results were obtained. These were photographic magnitudes for the interval 10.5–17.5,[3] and, for the most part, were in excellent agreement with the Harvard results which, in the meantime, had been published in *H.C.*, No. 170.

The next step was the extension of the photographic scale in the direction of the brighter stars. The provisional magnitudes[4] were in good agreement with independent determinations by Parkhurst[5] and Schwarzschild,[6] but presented a serious divergence from the Harvard results, which thus far has not been satisfactorily explained.

For the extension of the scale to the fainter stars certain long-exposure plates, some of them taken with diaphragms and screens, were next reduced. The comparison of these results with those previously found in the region 10–15 gave material for the determination and discussion of systematic errors and led eventually to the scale finally adopted for the interval from the tenth to the twentieth magnitude.

[1] *Contributions from the Mount Wilson Solar Observatory*, No. 97.

[2] *Publications of the Carnegie Institution of Washington.*

[3] "Magnitude Scale of the Polar Sequence" (read at the fourteenth meeting of the Astronomical and Astrophysical Society of America), *Science*, N.S., **37**, 34, 1913.

[4] *Mt. Wilson Contr.*, No. 70; *Astrophysical Journal*, **38**, 241, 1913.

[5] "Yerkes Actinometry," *Astrophysical Journal*, **36**, 169, 1912.

[6] "Göttingen Aktinometrie," *Astron. Mitt. d. Kgl. Sternwarte zu Göttingen*, No. 14 B, p. 42, 1912.

Finally, the extension of the scale in the direction of the bright stars was thoroughly revised and strengthened by the inclusion of a large number of additional photographs.

The procedure for the determination of the photo-visual scale has been similar, but much more direct.

Although the methods used for the observations and reductions have been fully described in *Mt. Wilson Contr.*, No. 80,[1] it may be recalled that circular diaphragms and screens of wire gauze are generally employed for the reduced-intensity exposures; further, that the objects observed are grouped into (*a*) intermediate stars (magnitudes 10–18), (*b*) bright stars (brighter than *a*), (*c*) faint stars (fainter than *a*), for each of which the method of treatment is somewhat different. Finally, it has been found convenient to separate the observations of the intermediate stars into those of short and long exposure.

The distribution of the observational data is shown by Table I. The procedure followed in securing the photographs is described in *Mt. Wilson Contr.*, No. 70, p. 5, and No. 80, p. 16.[2]

TABLE I

SUMMARY OF PLATES USED

Star Group	Photographic Scale			Photo-visual Scale		
	Exposure	No. Plates	Apertures*	Exposure	No. Plates	Apertures
Intermediate—						
Short exposure.	1^m to 11^m	15	60, 32, 14, 8, *G*, *g*, *S*	5^m and 20^m	2	60, 32, 14
Long exposure.	30 to 60	14	60, 32, 14	45^m	2	60, 32
Bright.....	1 or 2	213	See Table V	3^m or 4^m	122	See Table VIII
Faint.....	3^h to 5^h	5	60	4^h	2	60

* *G* and *g* are screens of wire gauze, the former placed over the end of the tube, the latter in front of the plate; *S* is a 60° sector diaphragm. For further details of constants, etc., see *Mt. Wilson Contr.*, No. 80, p. 11.

II. PHOTOGRAPHIC SCALE FOR INTERMEDIATE STARS

As stated above, the reduction began with the short-exposure (SE) photographs of the intermediate stars. Magnitudes on an

[1] "Photographic Photometry with the 60-Inch Reflector of the Mount Wilson Solar Observatory," *Astrophysical Journal*, **39**, 307, 1914.

[2] *Astrophysical Journal*, **38**, 245, 1913; **39**, 322, 1914.

absolute scale were derived for each combination of apertures by the method described in *Mt. Wilson Contr.*, No. 80, p. 23.[1] The zero point was in each case determined by the magnitudes of *H.C.*, No. 170. The results for individual stars were combined into means, and the residuals were discussed for systematic errors depending upon the apertures. The degree of accordance for the different apertures and a comparison with *H.C.*, No. 170, are shown in Table IX, *Mt. Wilson Contr.*, No. 80, p. 31.[2]

The next step was the determination of magnitudes from the long-exposure (LE) photographs, the method of reduction being the same as before, except in the case of three plates which were reduced by a method described on p. 214.

All of the plates were measured with photometric scale III (*Mt. Wilson Contr.*, No. 80, p. 19[3]), which is approximately a uniform scale of magnitudes; but, as is the case with all such scales, local irregularities affect the individual readings. The residuals from the LE and SE plates afforded abundant material for the determination of these errors; not only were the scale-readings different for a given star on the SE and LE plates, but further diversity was introduced by the numerous images of varying size obtained with the screens and diaphragms. The residuals for the LE and SE plates were first discussed separately for fear that small differences in the magnitude-scales for the two series might influence the results. As the correction-curves thus obtained were practically identical, they were combined into a mean curve based upon about 2800 residuals. No star with less than 10 residuals was included in the discussion, and even then it was not used unless the scale-readings were well distributed over the scale.

All of the residuals were then corrected with the aid of the final curve, and the mean magnitudes for the different stars were revised. A comparison of the SE and LE results for the 58 stars included in both series is shown in the fifth column of Table II, the unit being 0.01 magnitude. The number of individual magnitudes entering into each group from the SE and LE plates, respectively, appears in the eighth column. A comparison of the mean magni-

[1] *Astrophysical Journal*, **39**, 329, 1914.

[2] *Ibid.*, p. 337, 1914.

[3] *Ibid.*, p. 325, 1914.

tudes from all the plates with those of *H.C.*, No. 170, is given in the next to the last column.

TABLE II

RESULTS FROM SE AND LE PLATES

GROUP	MEAN MAG.	SCALE-READING		LE−SE	REL. WEIGHT	NO. STARS	NO. MAGS.	COMP. WITH *H.C.* NO. 170	
		SE	LE					MW−HC	No. Stars
1.....	10.6	.....	.....	+ 6	23	4	136, 29	+ 2	3
2.....	12.6	.....	.....	0	81	6	282,115	− 2	8
3.....	13.4	7.8	2.8	+ 1	123	12	355,202	+ 1	5
4.....	14.3	10.7	6.0	0	101	12	219,203	+ 3	3
5.....	14.8	12.5	7.9	+ 2	104	9	228,210	− 4	5
6.....	15.5	14.6	10.4	+ 5	50	7	83,142	− 6	5
7.....	16.6	17.9	14.5	+10	43	8	74,112	−22	8
Totals						58	1377,1013		37

The weight of the first LE−SE difference is small, and the difference itself is not surprisingly large. The next four differences show a close accordance in the two series of results. The last two, however, require further examination. Turning to the Harvard comparison, we find the same systematic divergence for the faint stars that characterized the preliminary results from the SE plates.[1]

It was suspected that the origin of the small systematic difference in the SE and LE results would be found in the corrections applied to the original scale-readings to reduce them to the center of the plate. With the 60-inch reflector these corrections are large, and their direct determination, especially for the faint stars, is difficult. As the distance error for the diaphragm apertures is negligible, or at least very small, it is evident that incorrect values for the full aperture must systematically affect the calculated scale of magnitudes.

The corrections which had been used were those resulting from the provisional investigation described in *Mt. Wilson Contr.*, No. 80, p. 20.[2] This gave a linear relation between the correction and the distance from the center of the plate, and further, for the full aperture, a relation between error and size of image defined by the

[1] *Mt. Wilson Contr.*, No. 70, p. 4; No. 80, p. 31; *Astrophysical Journal*, **38**, 244, 1913; **39**, 337, 1914.

[2] *Astrophysical Journal*, **39**, 326, 1914.

curve on p. 22 of that article. Fortunately, the data from the photographs under discussion were sufficient to permit a thorough examination of the question. The number of separate results for each star was large, and, in general, the range in the distance from the center of the plate was considerable, for the centering of the field was different on different photographs.

The residuals for the full-aperture results from about a hundred stars were arranged in groups, each covering one interval of scale-reading and 2 mm of distance. About 2000 residuals were used although only those from stars having numerous and well-distributed observations were included. In order to reduce accidental irregularities, overlapping means were formed for the groups. The results were then plotted, those relating to a single scale-reading defining a curve whose abscissae were distances from the center of the plate, and whose ordinates were corrections which, applied to the individual magnitudes, would remove any systematic dependence upon brightness and distance; in other words, would reduce the individual results to the mean scale. The mean scale, however, is not the true scale, for, as just remarked, the use of an erroneous correction for distance has affected the result.

Two corrections were therefore applied to the calculated magnitudes: (*a*) the ordinate δD of the correction-curve, corresponding to the position and size of the image, which reduced the individual results to the mean scale; (*b*) a scale correction, δm, to reduce from the mean scale to that which would have been obtained had the true distance-correction been used. The final solution could also have been obtained by repeating the calculation from the beginning with the revised distance-correction, but this would have been a very laborious operation.

An examination of the curves giving the values of δD shows that the original distance-correction was substantially correct, except for very large and very small images for which the results have been overcorrected. The curves further show that for all the intermediate and fainter images the assumption of a linear relation between distance-correction and distance is permissible. For the brighter images, however, an appreciable deviation from this relation is now apparent.

To determine the extent to which the scale has been affected by the use of the original distance-correction, it is necessary to know how much the correction was in error. This may be determined by displacing the δD-curves parallel to themselves in a vertical direction until they pass through the origin, for the correction must be zero at the center of the plate.[1] The ordinates of the displaced curves are the required errors.

The determination of the influence of these errors upon the magnitude-scale is now a simple matter. We have only to assume a series of hypothetical observations s and s_1 representing the scale-readings for a full aperture and a diaphragm exposure, respectively. These we transform into magnitudes by the usual process. We then correct the full-aperture readings s by the amount of the error in the original distance-correction and repeat the calculation. The difference in the two series of magnitudes is the required scale correction δm, which is conveniently expressed as a function of the scale-reading.

Two points, however, must be noted: First, in reducing the hypothetical observations, we must use for the constant of the diaphragm a value corresponding to the real observations, taking care, further, to select for the scale-readings values such that the differences $\Delta s = s_1 - s$ agree approximately with the observations. Secondly, the change in the distance-correction by which the values of s are modified before the repetition of the reduction to magnitudes must correspond to the mean distance of the stars actually observed.

It is further tacitly assumed that the distance-correction for the reduced aperture is negligible, or at least requires no revision. As a matter of fact, the discussion of about a thousand residuals for the 32- and 14-inch diaphragms showed only minute deviations, which, although systematic, have been disregarded because they are without influence upon the scale.

[1] At first sight, errors of focus would seem to require a modification of this statement; but for a reflector, images off the axis are always larger than central images. In other words, the increase in the images due to the aberrations of the mirror is large as compared with that due to curvature of the field. Moreover, in the present case, errors of focus play a very minor part, for with the diaphragm and screen plates the exposures were short, or moderate at most, and the focus was always carefully watched.

With regard to the first of the foregoing points, it may be remarked that several different apertures, with correspondingly different reduction constants, have been employed in reducing the plates. To take this circumstance into account, it is only necessary to reduce the hypothetical observations with the mean of the reduction constants actually used.

It was thus found that for scale-readings less than 12 no correction of the magnitude scale was required. For larger scale-readings the corrections are given in the second column of Table III. These results apply only to the plates taken with diaphragms. Those with which the wire screens were used require no scale correction whatever. Since the distance-correction with the screen is the same as that without the screen,[1] an erroneous correction, used for both full and reduced intensity images, can have no influence upon the *mean* scale, that is, the scale established for a large number of stars of each degree of brightness uniformly scattered over the plate. Individual magnitudes will be in error, but these compensate each other in the mean. The matter is easily tested with the aid of hypothetical observations as above. For this purpose the reduced intensity scale-readings, before the repetition of the calculation, should receive the same modification as those of the full aperture. The two series of magnitudes will then differ only by a constant.

It has been assumed that these remarks also apply to the three plates taken with the 60° sector diaphragm. As this method of reducing the intensity has been but little used, its distance-correction has not been investigated. It seems probable that the correction would not be unlike that for the full aperture, and, in the absence of definite information, this assumption has been accepted as valid.

Before correcting the several thousand individual magnitudes in the manner indicated, information was desired as to whether this procedure would account for the systematic difference between the SE and LE plates shown in Table II. This information was, however, already available, for an examination of the results on the assumption that the scale error depended only on the size of the image had shown what that error must be. Its value was derived by a step-by-step process based on the data in Table II.

[1] *Mt. Wilson Contr.*, No. 80, p. 21; *Astrophysical Journal*, **39**, 327, 1914.

Since for scale-readings less than 12 the differences LE−SE are zero, it follows from the foregoing assumption that, as far as this limit, both scales are correct. The differences for Groups 5 and 6 of Table II are therefore the errors of the SE magnitude-scale at points whose photometric scale-readings are 12.5 and 14.6. We thus know the error of the LE scale for reading 14.5 (Group 7), and with the aid of the corresponding LE−SE difference find the error for reading 17.9.

The results of the calculation thus outlined are shown in the third column of Table III alongside those derived from the revision

TABLE III

ERROR OF PROVISIONAL SCALE

SCALE-READING	δm	
	DC	SE and LE
	mag.	mag.
12	+0.02	+0.01
13	.03	.02
14	.04	.04
15	.05	.05
16	.06	.07
17	.10	.10
18	.16	.14
19	0.26	0.23

of the distance-correction. As the two series of values are practically identical, we infer that the difference between the scales from the SE and LE plates may be attributed entirely to errors in the original distance-correction.

Proceeding to the revision of the individual magnitudes, the two corrections δD and δm were applied to each residual. The mean values were then revised and the results for the SE and LE plates again compared. The accordance of the two scales (Table IV) is now all that can be desired and indicates that there are no remaining errors of any consequence which depend upon the exposure time or the size of the images. The comparison with *H.C.*, No. 170, in the last column of Table IV is less satisfactory, however. The differences MW−HC are but little changed as compared with those in Table II, and the results for the faint stars which now

appear in the reduction show that the divergence beginning at magnitude 15 continues to increase and becomes ultimately very large.

It has been remarked (p. 208) that three of the LE plates received special treatment. As the exposure time for these was one hour, they are of great importance in establishing the scale for the fainter stars and a more detailed account of their reduction is desirable.

The necessity for special treatment arose from the fact that the reduced intensity exposures were obtained with a 6-inch diaphragm whose constant is 4.81 mag. With constants as large as this, the usual method[1] of deriving the scale cannot safely be applied. The

TABLE IV

FINAL RESULTS FOR SE AND LE PLATES

MW Mean Mag.	LE−SE	Rel. Weight	MW−HC
	mag.		mag.
10.6	+0.018	36	−0.05
11.7	+ .007	49	− .05
12.8	− .007	76	+ .03
13.4	.000	100	+ .02
14.0	+ .023	74	+ .03
14.3	− .026	71	+ .03
14.8	+ .004	98	− .03
15.5	+ .034	77	− .06
16.8	+0.017	34	− .17
17.9			− .39
18.5			− .53
19.1			−0.87

range of scale-reading for the secondary images of stars with measurable full-intensity images is too small to permit the use of the ordinary interpolation process.

On this account, the scale, as far as the fifteenth magnitude, was assumed to be known. The adopted magnitudes were plotted against the scale-readings of the primary images, and at the same time, the adopted magnitudes, less the amount of the reduction constant, were plotted against the readings of the corresponding secondary images. Smooth curves were drawn, from which were read magnitudes for all of the images shown. The scale for the faint stars thus found is not, of course, independently derived, for

[1] *Mt. Wilson Contr.*, No. 80, p. 23; *Astrophysical Journal*, **39**, 329, 1914.

the method merely transfers an adopted scale to the region of the fainter objects. The results, however, are in close agreement[1] with those from other LE plates, which, because of smaller constants, could be independently reduced. The zero point is of course that of the adopted scale.

III. PHOTOGRAPHIC SCALE FOR FAINT STARS

The magnitudes derived from the three LE plates just discussed carry the scale somewhat below the limit (magnitude 18) which is regarded as separating the intermediate from the faint stars, but as they depend upon diaphragm exposures, it has been convenient to group them with the intermediate stars. On the other hand, one plate of moderately short exposure, because of the manner in which it was taken, appears among the faint-star plates. We now turn to the discussion of this latter portion of the data.

The plates for the faint stars usually received two exposures, both with the full aperture, one long and one short. The method of reduction, which involves an extrapolation, though a fairly reliable one, is described in *Mt. Wilson Contr.*, No. 80, pp. 5, 26.[2] The scale for the intermediate stars must be known. As this was the case for the objects brighter than the eighteenth magnitude, mean results for about 160 stars, none including less than 8 or 10 individual values, were available for the reduction. As each of the five plates was reduced with the revised distance-correction no subsequent corrections were required.

The results extend the photographic scale to the twentieth magnitude and include values for the brightness of a large number of objects not shown by the other plates. They also afford additional values for many of the intermediate stars, which have been combined with the original magnitudes to reduce the effect of accidental errors. The revised mean magnitudes, together with the magnitudes of the additional stars, have been entered in the catalogue.[3]

[1] See residuals for Plates 196, 200, and 204 in Table XII.

[2] *Astrophysical Journal*, **39**, 311, 332, 1914.

[3] With a few exceptions no results appear in the catalogue given in Table IX unless both photographic and photo-visual magnitudes have been determined.

IV. PHOTOGRAPHIC SCALE FOR BRIGHT STARS

The method here applied has been fully described and illustrated in *Mt. Wilson Contr.*, No. 70,[1] and little in the way of detail need be added. It involves a transference of the scale for the intermediate stars to the region of the brighter objects. The operation is repeated with a number of different apertures, and the results for each give a scale for the bright stars which is homogeneous with the adopted scale unless there is some unsuspected form of error; the slope of the scale found with each aperture, independently of error in the reduction constant, is the same as that of the adopted scale. An error in the constant affects the calculated magnitudes by a fixed amount; hence their relative values should be correct. Further, since the separate scales overlap, a comparison of results for the various apertures controls the errors of the constants.

As stated above, the data for the bright stars in *Mt. Wilson Contr.*, No. 70,[2] have been strengthened by the inclusion of additional plates. Further, six stars fainter than the tenth magnitude were added to the list in order that the results by the method used for the bright stars might overlap considerably those derived from the diaphragm and screen plates for the intermediate stars. Finally, the earlier plates were entirely re-reduced, the revised distance-correction and the magnitudes whose derivation has been described in Section 2 being used for this purpose.

The results, now based upon 662 individual magnitudes as against 295 in the original investigation, are given in Table V which corresponds to Table II in *Mt. Wilson Contr.*, No. 70. The second column gives the final magnitudes referred to the zero point defined by HC magnitudes between 10 and 15, which thus far has been consistently used. As before, the headings indicate the apertures and the approximate reduction constants used in establishing the separate scales. "Various" includes several different apertures which were only occasionally employed. The tabular values are the residuals, referred to the means in the second column, of the results for each star as found with each aperture. The number of values included in each residual is indicated by the attached number

[1] *Astrophysical Journal*, **38**, 241, 1913. [2] *Loc. cit.*

TABLE V

PHOTOGRAPHIC MAGNITUDES OF BRIGHT STARS

No.	MW Pg. Mag.	40 1.1	32 2.0	14 3.0	*G* 3.1	9 3.9	6 4.8	32+*G* 5.0	14+*G* 6.0	*G*₂ 6.1	9+*G* 7.0	6+*G* 7.9	14+2*G* 9.2	Various	MW *Minus* HC
1*s*	2.14	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	−7 (8)	+2 (32)	−57
1	3.99	.....	.....	.....	.....	.....	.....	.....	.....	.....	− 9 (4)	− 2 (4)	+3 (6)	+6 (6)	−48
2	4.90	.....	.....	.....	.....	.....	.....	.....	−15 (5)	+ 3 (3)	+ 4 (4)	+18 (3)	.....	.....	−34
3	5.43	.....	.....	.....	.....	.....	.....	.....	− 3 (6)	− 5 (5)	+ 2 (6)	+ 8 (3)	+6 (2)	.....	−31
4	5.51	.....	.....	.....	.....	.....	.....	.....	− 4 (6)	−16 (4)	+ 5 (7)	+14 (4)	+2 (2)	.....	−40
5	6.05	.....	.....	.....	.....	.....	−16 (5)	+ 6 (5)	+ 5 (5)	0 (4)	+ 5 (6)	.....	.....	.....	−34
2*s*	6.05	.....	.....	.....	.....	−19 (3)	−13 (6)	− 2 (4)	+16 (6)	+ 2 (7)	+ 4 (7)	.....	.....	.....	−33
1*r*	6.21	.....	.....	.....	.....	.....	− 4 (2)	.....	+ 2 (9)	−13 (8)	+ 8 (6)	+16 (2)	.....	.....	−48
3*s*	6.24	.....	.....	.....	.....	−26 (1)	−13 (4)	− 5 (3)	+ 7 (5)	− 8 (3)	+13 (6)	.....	.....	.....	−30
6	6.71	.....	.....	.....	.....	+ 1 (3)	+ 5 (4)	+10 (2)	− 2 (3)	− 8 (4)	.....	.....	.....	.....	−27
7	7.01	.....	.....	.....	.....	−14 (5)	− 3 (5)	+10 (4)	+ 5 (7)	+ 3 (5)	.....	.....	.....	.....	−17
2*r*	7.54	.....	+21 (1)	−12 (2)	−11 (4)	− 4 (3)	+ 1 (3)	−13 (3)	+19 (3)	+ 9 (3)	.....	.....	.....	.....	−19
8	7.92	.....	.....	−13 (5)	− 1 (5)	+ 3 (5)	− 3 (6)	+18 (3)	+11 (6)	− 6 (6)	.....	.....	.....	.....	−18
9	8.48	.....	+22 (4)	+ 2 (2)	− 3 (6)	+ 7 (4)	− 2 (6)	−20 (4)	.....	.....	.....	.....	.....	.....	−22
3*r*	8.56	.....	−22 (2)	− 1 (4)	+12 (4)	− 1 (4)	0 (2)	+ 4 (2)	.....	.....	.....	.....	.....	+1 (1)	− 6
10	8.72	.....	+ 1 (5)	+ 9 (3)	+ 2 (3)	− 9 (4)	+ 3 (3)	− 3 (3)	.....	.....	.....	.....	.....	.....	−17
4*r*	8.82	.....	−20 (2)	+ 6 (5)	+ 8 (3)	+ 5 (5)	− 1 (3)	−20 (2)	.....	.....	.....	.....	.....	.....	−15
11	9.33	.....	− 4 (6)	− 6 (7)	+ 7 (7)	+ 2 (6)	.....	+ 2 (2)	.....	.....	.....	.....	.....	.....	− 9
12	9.69	−10 (4)	− 8 (5)	− 7 (5)	+ 7 (5)	+11 (6)	.....	.....	.....	.....	.....	.....	.....	.....	− 4
5*r*	9.73	0 (4)	−13 (6)	− 8 (6)	+11 (5)	+21 (3)	.....	.....	.....	.....	.....	.....	.....	.....	− 5
4*s*	9.85	+ 1 (3)	0 (4)	− 4 (4)	+ 4 (4)	+ 2 (4)	.....	.....	.....	.....	.....	.....	.....	.....	−14
6*r*	10.06	−10 (6)	0 (4)	− 1 (6)	+10 (6)	+ 4 (4)	.....	.....	.....	.....	.....	.....	.....	.....	−11
13	10.13	0 (4)	0 (6)	− 8 (5)	+ 8 (4)	.....	.....	.....	.....	.....	.....	.....	.....	.....	− 4
7*r*	10.51	+ 6 (2)	− 1 (2)	+ 4 (1)	−14 (1)	.....	.....	.....	.....	.....	.....	.....	.....	.....	− 6
14	10.52	− 4 (2)	− 2 (3)	+ 4 (3)	+ 2 (2)	.....	.....	.....	.....	.....	.....	.....	.....	.....	0
15	10.90	−14 (4)	− 8 (4)	+14 (4)	+ 8 (4)	.....	.....	.....	.....	.....	.....	.....	.....	.....	− 4
6*s*	10.98	−10 (3)	− 4 (3)	+14 (1)	+16 (2)	.....	.....	.....	.....	.....	.....	.....	.....	.....	+ 1
8*r*	11.12	−11 (5)	+ 2 (5)	+14 (5)	+ 8 (2)	.....	.....	.....	.....	.....	.....	.....	.....	−12 (3)	+ 6
16	11.21	0 (6)	− 1 (7)	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	+ 6 (2)	− 5
17	11.53	− 8 (8)	+ 8 (8)	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	+ 4
18	11.90	− 4 (8)	+ 5 (8)	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	− 2
Systematic deviations		−6 (59)	−1 (85)	−1 (68)	+5 (67)	0 (60)	−5 (49)	−1 (37)	+4 (61)	−4 (52)	+5 (46)	+10 (16)	−1 (18)	+ 2 (44)	

in parentheses.[1] The weighted mean residuals appearing at the bottom are the systematic deviations of the results for each aperture from the mean of all. These quantities are closely related to the errors of the reduction constants.

It is unnecessary to repeat here the details of the discussion undertaken in *Mt. Wilson Contr.*, No. 70, as the results are essentially the same. The following, however, may be noted:

1. No marked progression in the residuals appears in any of the columns. The parallelism of the constituent scales with the mean scale is therefore close.

2. The systematic deviations at the bottom of the table are small; hence the errors in the reduction constants are also small and probably have had but little influence upon the mean scale.

3. The re-reduction and the inclusion of new data have diminished the accidental errors, but have not materially altered the scale. The divergence from *H.C.*, No. 170, remains substantially as before.

4. Since the constituent scales are sensibly parallel, they must all show the same divergence from the results of *H.C.*, No. 170.

A comparison of the overlapping portion of the scale here established with that for the intermediate stars is shown in the first half of Table VI. In view of the fact that the IS results are here subject to some uncertainty because of large distance error, the agreement is as good as can be expected.

There remains still to be considered the influence of the apparent magnitude to which the bright stars have been reduced in determining their real magnitudes.[2] This is shown in the first part of Table VII. The second column gives the mean residual for all the results derived from apparent magnitudes within the limits shown in the first column. Thus the 69 values for bright stars found by reducing to apparent magnitudes between 9.5 and 11.0 are fainter by 0.08 magnitude, on the average, than the final magnitudes in the second column of Table V. This difference is the zero-point

[1] Note that the algebraic signs of the residuals are here reversed as compared with those of *Mt. Wilson Contr.*, No. 70. Thus for star 12, the residual −10 for the 40-inch diaphragm indicates that the mean of the four values found with this aperture is 9.79.

[2] *Mt. Wilson Contr.*, No. 70, pp. 16–22; *Astrophysical Journal*, **38**, 256–262, 1913.

error of this particular portion of the results relative to the mean of them all. Its origin will be discussed at a later time. Now it need only be noted that, while obviously systematic, the dependence upon apparent magnitude is small and probably without influence upon the mean scale for the bright stars.

TABLE VI

COMPARISON OF OVERLAPPING SCALES FOR BRIGHT AND INTERMEDIATE STARS

STAR NO.	PHOTOGRAPHIC				PHOTO-VISUAL			
	BS	IS	No.	B−I	BS	IS	No.	B−I
13.....	10.13	.....	19, 0	.....	10.37	10.46	11, 5	− 9
14.....	10.52	10.59	10, 47	− 7	10.52	10.68	12, 6	−16
15.....	10.90	10.76	16, 14	+14	10.92	10.97	9, 1	− 5
16.....	11.21	11.22	15, 28	− 1	11.19	11.40	11, 5	−21
17.....	11.53	11.43	16, 27	+10	11.27	11.37	8, 5	−10
18.....	11.90	11.85	16, 33	+ 5	11.92	11.92	8, 6	0
7*r*.....	10.51	10.55	6, 28	− 4	9.91	9.96	18, 10	− 5
8*r*.....	11.12	10.92	20, 12	+20	10.44	10.54	12, 5	−10
5*s*.....	.....	10.69	0, 60	.....	10.04	10.16	17, 11	−12
6*s*.....	10.98	.....	9, 0	.....	10.78	10.72	9, 4	+ 6
Means..				+ 5				− 8

TABLE VII

DEPENDENCE UPON APPARENT MAGNITUDE

RANGE OF APPARENT MAG.	PHOTOGRAPHIC		PHOTO-VISUAL	
	Residual	No.	Residual	No.
9.5–11.0.....	−8	69	−2*	19
11.0–11.5.....	−2	72	−6	68
11.5–12.0.....	−1	92	−1	55
12.0–12.5.....	0	132	+3	76
12.5–13.0.....	−1	83	0	62
13.0–13.5.....	+3	125	+4	60
13.5–14.0.....	+5	66	+2	27
14.0–14.7.....	+6	23	.....	.....
Totals.....		662		367

* The range of apparent magnitude for this value is 10.1–10.8.

V. THE PHOTO-VISUAL SCALE

The photo-visual scale has been determined in precisely the same manner as the photographic; but the operations have been simpler and the labor much less, for fewer plates were used and the irregu-

TABLE VIII

Photo-visual Magnitudes of Bright Stars

No.	MW Pv. Mag.	60 0	40 1.1	32 2.0	14 3.0	G 3.1	9 3.9	40+G 4.2	6 4.8	14+G 6.0	G_2 6.1	9+G 7.0	40+G_2 7.2	Various	MW *Minus* HC
1s	2.11	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0 (23)	− 1
1	4.40	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	− 2 (2)	− 2 (2)	+ 1 (5)	− 4
1r	5.12	.....	.....	.....	.....	.....	.....	.....	.....	−14 (2)	− 8 (3)	+ 8 (2)	.....	+13 (3)	−14
2	5.31	.....	.....	.....	.....	.....	.....	.....	.....	0 (2)	−17 (3)	+10 (1)	0 (2)	+14 (3)	− 7
3	5.59	.....	.....	.....	.....	.....	.....	.....	− 7 (2)	− 4 (2)	− 1 (3)	+ 5 (4)	.....	.....	− 3
4	5.87	.....	.....	.....	.....	.....	.....	.....	.....	−23 (1)	+ 9 (3)	+ 9 (2)	− 4 (2)	−14 (1)	+ 1
2s	6.36	.....	.....	.....	.....	.....	.....	.....	−18 (3)	+15 (3)	− 3 (3)	+20 (1)	.....	.....	+ 8
3s	6.38	.....	.....	.....	.....	.....	.....	.....	−18 (2)	+ 5 (2)	− 9 (3)	+18 (3)	.....	.....	+ 5
2r	6.38	.....	.....	.....	.....	.....	.....	.....	− 9 (3)	+14 (2)	− 3 (3)	+13 (1)	− 2 (3)	.....	−17
5	6.50	.....	.....	.....	.....	.....	.....	.....	−15 (2)	+10 (2)	− 1 (4)	+ 5 (2)	.....	.....	+ 7
6	7.08	.....	.....	.....	.....	.....	− 6 (2)	.....	− 2 (3)	− 1 (3)	+12 (2)	.....	.....	.....	+ 7
7	7.55	.....	.....	.....	.....	.....	.....	.....	− 2 (5)	+ 8 (4)	− 8 (3)	.....	.....	.....	+11
3r	7.59	.....	.....	.....	− 4 (1)	.....	− 4 (2)	+ 4 (2)	+ 4 (2)	−13 (1)	+19 (1)	.....	.....	− 2 (2)	+ 2
8	8.16	.....	.....	− 9 (4)	− 7 (3)	+13 (3)	+ 6 (4)	.....	.....	.....	.....	.....	.....	.....	+19
4r	8.29	.....	.....	.....	− 4 (1)	+18 (2)	− 4 (1)	0 (2)	+ 4 (1)	.....	.....	.....	.....	−16 (2)	+ 3
5r	8.68	.....	.....	0 (4)	− 7 (2)	+10 (2)	+ 4 (2)	− 6 (2)	.....	.....	.....	.....	.....	.....	+ 1
9	8.84	.....	.....	.....	+ 4 (2)	− 2 (2)	− 1 (2)	− 8 (2)	+10 (2)	.....	.....	.....	.....	0 (2)	+23
10	9.10	.....	.....	−16 (2)	+ 9 (3)	+ 2 (3)	− 8 (2)	+11 (2)	.....	.....	.....	.....	.....	.....	+16
6r	9.24	.....	.....	−21 (3)	+ 6 (3)	+ 9 (3)	− 7 (1)	+10 (2)	.....	.....	.....	.....	.....	.....	− 1
11	9.56	.....	.....	− 2 (2)	− 4 (2)	− 1 (3)	+20 (1)	− 4 (2)	.....	.....	.....	.....	.....	.....	+26
12	9.83	.....	.....	− 4 (4)	− 1 (4)	+ 4 (4)	.....	.....	.....	.....	.....	.....	.....	.....	+29
4s	9.86	.....	.....	− 4 (3)	− 2 (4)	− 3 (2)	+ 3 (1)	+24 (1)	.....	.....	.....	.....	.....	.....	+28
7r	9.91	.....	−13 (4)	+ 1 (6)	+ 5 (6)	+ 6 (2)	.....	.....	.....	.....	.....	.....	.....	.....	+ 7
5s	10.04	.....	−12 (4)	+ 2 (5)	+ 5 (6)	+ 6 (2)	.....	.....	.....	.....	.....	.....	.....	.....	+18
13	10.37	.....	− 7 (4)	+ 6 (2)	−10 (2)	+13 (3)	.....	.....	.....	.....	.....	.....	.....	.....	+12
8r	10.44	0 (3)	− 1 (4)	− 4 (4)	+23 (1)	.....	.....	.....	.....	.....	.....	.....	.....	.....	+ 5
14	10.52	+ 2 (2)	+ 1 (3)	−13 (3)	+15 (2)	+ 4 (2)	.....	.....	.....	.....	.....	.....	.....	.....	+ 8
6s	10.78	+ 2 (3)	0 (3)	− 1 (3)	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	+ 3
15	10.92	.....	+ 2 (4)	− 5 (4)	+18 (1)	.....	.....	.....	.....	.....	.....	.....	.....	.....	+14
16	11.19	− 6 (3)	+ 3 (4)	+ 2 (4)	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	+12
17	11.27	+12 (4)	− 5 (3)	−31 (1)	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	+ 9
18	11.92	+ 1 (4)	+ 5 (3)	−16 (1)	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	− 1
Systematic deviations		+2 (19)	−3 (36)	−5 (55)	+2 (43)	+6 (33)	0 (18)	+2 (15)	−6 (25)	+3 (24)	−3 (31)	+9 (18)	− 2 (9)	+1 (41)	

larities of the photometric scale and the errors of the distance-correction tables had previously been investigated.

The intermediate stars require no comment beyond the statement that the provisional zero point was that defined by the visual magnitudes of *H.C.*, No. 170, which are fainter than 9.8. The results for the bright stars are given in Table IX, which is similar in arrangement to Table V. The mean magnitudes in the second column depend upon 367 individual values.

Although the visual scale of *H.C.*, No. 170, and the Mount Wilson photo-visual scale coincide at the sixth and the twelfth magnitudes, there are important differences at intervening points. An appreciable color equation also makes its appearance, for it will be noted that the differences MW−HC are systematically smaller for the red stars than for the white.

The accordance of the overlapping portions of the scales for the bright and the intermediate stars is shown by the second half of Table VI. The systematic difference of 0.08 magnitude is probably due to an error in the IS scale, which in this region is somewhat uncertain.

Finally, the dependence of the scale for the bright stars upon the apparent magnitudes from which the individual values have been derived appears in Table VII. Here the residuals are again slightly systematic, but satisfactory.

VI. DETERMINATION OF THE ZERO POINTS

The zero-point corrections have been determined in such a way that both photographic and photo-visual magnitudes of the white stars near the sixth magnitude have the same mean value as the corresponding visual magnitudes of *H.C.*, No. 170. The objects actually used in determining the corrections were Nos. 2–6 and 2*s* and 3*s*. As only two of these are of spectrum A0, an allowance for color was made in the case of the photographic scale. The resulting corrections are +0.40 magnitude for the photographic scale, and −0.03 magnitude for the photo-visual.

VII. THE CATALOGUE

The complete catalogue includes 645 objects. Photographic magnitudes have been derived for 617 of these and photo-visual

magnitudes for 339. The catalogue in Table IX, however, contains only 329, for with the exception of Polar Sequence stars no object has been entered unless both photographic and photo-visual magnitudes have been determined.

For convenience the Polar Sequence stars appear at the beginning of the table, arranged in the order of their numbers as given in *H.C.*, No. 170. The numbers of the remaining stars, unless a letter is attached, are those of *Harvard Annals*, **48**, Part I. Those with letters are faint objects near the *H.A.* star of the same number. Their rectangular co-ordinates for 1900 are given in Table X.

The magnitudes in the second and third columns of Table IX were obtained by applying to the preliminary values the zero-point corrections given above. For the stars appearing in Table VI, the weighted means of the IS and BS results were the values thus corrected and entered in the catalogue. The number of separate determinations entering into each photographic and photo-visual magnitude, respectively, is shown in the fifth column. The remaining columns contain comparisons of the Mount Wilson photographic scale with that of Harvard[1] and of Greenwich[2] and with the results of Dziewulski[3] obtained with the 80-cm refractor of the Potsdam Observatory.

VIII. SYSTEMATIC DIFFERENCES

The systematic differences affecting the results for the bright stars have already been shown in Tables V and VIII. Those for the photographic magnitudes of the intermediate stars which depend on the method of reducing the intensity are given in Table XI. The agreement is much better than it was before the revision of the distance-correction.[4] The circular diaphragms give practically identical results, but the screens still show divergences of a few hundredths of a magnitude. The last two columns of the table

[1] *H.C.*, No. 170, 1912.

[2] *Monthly Notices*, R.A.S., **74**, 40, 1913.

[3] *Astronomische Nachrichten*, **198**, 65, 1914.

[4] *Mt. Wilson Contr.*, No. 80, p. 31, Table IX; *Astrophysical Journal*, **39**, 337, 1914 Note that the signs of the residuals must be reversed to make them comparable with Table XI of this paper.

TABLE IX

Catalogue of Magnitudes

No.	Magnitude		Color Index	No. Obs.	MW *Minus* HC	MW *Minus* GR	MW *Minus* DZ	MW *Minus* HH_W	MW *Minus* GR_1	MW *Minus* DZ_1
	Pg	Pv								
1.....	4.39	4.37	0.02	20, 9	− 8	.....	.....	−16	.....	.....
2.....	5.30	5.28	0.02	15, 11	+ 6	.....	.....	− 1	.....	.....
3.....	5.83	5.56	0.27	22, 11	+ 9	.....	.....	− 1	.....	.....
4.....	5.91	5.84	0.07	23, 9	0	.....	.....	− 8	.....	.....
5.....	6.45	6.47	−0.02	25, 10	+ 6	.....	.....	− 2	.....	.....
6.....	7.11	7.05	0.06	16, 10	+13	.....	.....	+ 4	.....	.....
7.....	7.41	7.52	−0.11	26, 12	+23	.....	.....	+16	.....	.....
8.....	8.32	8.13	0.19	36, 14	+22	.....	.....	+11	.....	.....
9.....	8.88	8.81	0.07	26, 12	+18	.....	.....	+ 9	.....	.....
10.....	9.12	9.07	0.05	21, 12	+23	+29	+27	+15	+ 5	− 4
11.....	9.73	9.53	0.20	28, 10	+31	.....	.....	+20	.....	.....
12.....	10.09	9.80	0.29	25, 12	+36	.....	.....	+24	.....	.....
13.....	10.53	10.37	0.16	19, 16	+36	+27	.....	+26	0	.....
14.....	10.98	10.54	0.44	57, 18	+46	+36	+38	+33	+ 1	+10
15.....	11.22	10.89	0.33	30, 10	+28	+27	+19	+17	− 5	−10
16.....	11.62	11.23	0.39	43, 16	+36	+36	+38	+25	+ 2	+ 9
17.....	11.87	11.28	0.59	43, 13	+38	+40	+27	+22	+ 1	0
18.....	12.27	11.89	0.38	49, 14	+35	+30	+22	+22	− 3	− 7
19.....	12.69	12.28	0.41	78, 12	+41	+37	+37	+28	+ 3	+ 8
20.....	13.02	12.51	0.51	86, 12	+43	+41	+37	+29	+ 4	+ 9
21.....	13.33	12.48	0.85	37, 12	+51	+47	+16	+29	+ 1	−10
22.....	13.44	12.81	0.63	45, 11	+39	+42	+24	+22	+ 2	− 3
23.....	13.60	13.10	0.50	80, 12	+40	+40	+32	+25	+ 3	+ 4
24.....	13.93	13.33	0.60	71, 12	+43	+40	+33	+28	+ 1	+ 6
25.....	14.08	13.60	0.48	78, 12	+35	+33	+25	+22	− 3	− 3
26.....	14.64	13.72	0.92	74, 12	+45	+49	+28	+27	+ 1	+ 3
27.....	14.91	14.33	0.58	61, 7	+36	+35	+33	+22	− 4	+ 5
28.....	15.27	14.54	0.73	40, 7	+30	+34	+22	+15	− 9	− 5
29.....	15.82	15.21	0.61	40, 6	+30	+32	+ 8	+16	− 7	−19
30.....	16.18	15.44	0.74	34, 5	+28	.....	+12	+14	.....	−15
31.....	16.41	15.62	0.79	45, 6	+33	.....	+34	+18	.....	+ 8
32.....	16.76	15.58	1.18	33, 3	+28	.....	+46	+12	.....	+22
33.....	17.06	15.97	1.09	32, 3	+24	.....	.....	+ 7	.....	.....
34.....	17.24	16.29	0.95	24, 2	+13	.....	.....	− 1	.....	.....
35.....	17.63	16.94	0.69	20, 2	+27	.....	.....	+13	.....	.....
36.....	17.78	16.80	0.98	18, 2	+17	.....	.....	+ 4	.....	.....
37.....	18.01	16.81	1.20	16, 2	+21	.....	.....	+ 7	.....	.....
38.....	18.20	17.05	1.15	15, 2	+ 3	.....	.....	−10	.....	.....
39.....	18.58	17.13	1.45	14, 2	+ 5	.....	.....	− 9	.....	.....
40.....	18.87	17.29	1.58	11, 2	− 2	.....	.....	−15	.....	.....
41.....	19.02	17.47	1.55	8, 2	−11	.....	.....	−24	.....	.....
42.....	19.18	.....	.....	8	−36	.....	.....	−44	.....	.....
43.....	19.53	.....	.....	4	−55	.....	.....	−63	.....	.....
44.....	19.59	.....	.....	3	−71	.....	.....	−79	.....	.....
45.....	19.80	.....	.....	1	−80	.....	.....	−88	.....	.....
46.....	19.82	.....	.....	2	−114	.....	.....	−122	.....	.....
1*r*....	6.61	5.09	1.52	27, 10	− 8	.....	.....	−26	.....	.....
2*r*....	7.94	6.35	1.59	22, 12	+21	.....	.....	+ 3	.....	.....
3*r*....	8.96	7.56	1.40	19, 11	+34	.....	.....	+17	.....	.....
4*r*....	9.22	8.26	0.96	20, 9	+25	.....	.....	+11	.....	.....

TABLE IX—*Continued*

No.	Magnitude		Color Index	No. Obs.	MW *Minus* HC	MW *Minus* Gr	MW *Minus* Dz	MW *Minus* HH_w	MW *Minus* Gr_1	MW *Minus* Dz_1
	Pg	Pv								
5*r*	10.13	8.65	1.48	24, 12	+35	.....	.....	+16	.....	.....
6*r*	10.46	9.21	1.25	26, 12	+29	.....	.....	+11	.....	.....
7*r*	10.94	9.90	1.04	34, 28	+37	+40	+ 9	+22	−11	−16
8*r*	11.44	10.44	1.00	32, 17	+38	+50	.....	+24	0	.....
10*r*	.....	12.03	.....	5	.....	.....	.....	.....	.....	.....
11*r*	13.22	12.06	1.16	79, 12	+39	+56	+21	+25	+ 2	− 3
12*r*	13.84	12.46	1.38	82, 12	+50	+65	+26	+31	+ 5	+ 3
1*s*	2.54	2.08	0.46	40, 23	−17	.....	.....	−25	.....	.....
2*s*	6.45	6.33	0.12	33, 10	+ 7	.....	.....	− 2	.....	.....
3*s*	6.64	6.35	0.29	22, 10	+10	.....	.....	− 1	.....	.....
4*s*	10.25	9.83	0.42	19, 11	+26	.....	.....	+17	.....	.....
5*s*	11.09	10.06	1.03	60, 28	+41	+45	+22	+26	− 6	− 3
6*s*	11.38	10.73	0.65	9, 13	+41	+48	+10	+26	+ 7	−17
7*s*	12.61	12.10	0.51	70, 12	+30	+36	+36	+16	− 1	+ 8
8*s*	14.49	13.78	0.71	50, 12	+43	+37	+27	+27	− 5	0
9*s*	14.75	13.85	0.90	66, 12	+42	+42	+29	+25	− 5	+ 3
10*s*	15.29	14.49	0.80	45, 7	+41	+42	+31	+25	− 3	+ 5
11*s*	15.31	14.35	0.96	63, 10	+40	+37	+27	+22	−12	+ 2
12*s*	15.33	14.69	0.64	61, 7	+36	+31	+21	+21	− 9	− 6
13*s*	15.54	14.54	1.00	43, 3	+45	+55	+25	+27	+ 5	0
14*s*	15.99	15.07	0.92	47, 7	+38	+36	+ 3	+21	−12	−22
15*s*	16.57	15.71	0.86	41, 5	+29	.....	.....	+15	.....	.....
16*s*	16.86	15.50	1.36	36, 4	+28	.....	.....	+11	.....	.....
17*s*	17.19	15.89	1.30	27, 2	+22	.....	.....	+ 5	.....	.....
18*s*	17.94	16.91	1.03	19, 2	+ 8	.....	.....	+ 5	.....	.....
19*s*	18.16	16.95	1.21	15, 2	−14	.....	.....	−32	.....	.....
20*s*	18.60	17.19	1.41	13, 2	+ 4	.....	.....	− 9	.....	.....
21*s*	18.66	17.33	1.33	12, 2	− 1	.....	.....	−20	.....	.....
22*s*	18.75	17.13	1.62	11, 2	0	.....	.....	−18	.....	.....
23*s*	18.70	17.41	1.29	12, 2	−18	.....	.....	−38	.....	.....
24*s*	18.88	17.34	1.54	12, 2	0	.....	.....	− 9	.....	.....
25*s*	18.84	17.38	1.46	10, 2	−18	.....	.....	−31	.....	.....
26*s*	18.99	.....	.....	9	−30	.....	.....	−38	.....	.....
27*s*	19.08	17.43	1.65	9, 2	−22	.....	.....	−30	.....	.....
28*s*	19.23	.....	.....	8	−33	.....	.....	−41	.....	.....
29*s*	19.28	.....	.....	6	−76	.....	.....	−84	.....	.....
30*s*	19.52	.....	.....	3	−66	.....	.....	−74	.....	.....
31*s*	19.49	.....	.....	3	−69	.....	.....	−77	.....	.....
32*s*	19.56	.....	.....	4	−62	.....	.....	−70	.....	.....
33*s*	19.68	.....	.....	4	−56	.....	.....	−64	.....	.....
34*s*	19.70	.....	.....	2	−60	.....	.....	−68	.....	.....
35*s*	19.86	.....	.....	3	−60	.....	.....	−68	.....	.....
36*s*	19.48	.....	.....	3	−108	.....	.....	−116	.....	.....
37*s*	19.65	.....	.....	2	−93	.....	.....	−101	.....	.....
38*s*	20.10	.....	.....	1	−90	.....	.....	−98	.....	.....
119	17.38	15.97	1.41	2, 1	.....	.....	.....	.....	.....	.....
119*a*	17.88	16.40	1.48	1, 1	.....	.....	.....	.....	.....	.....
124	16.50	15.09	1.41	4, 3	.....	.....	.....	.....	.....	.....
125	15.12	14.37	0.75	2, 5	.....	+70	+76	.....	+27	+50
125*a*	16.90	15.91	0.99	1, 2	.....	.....	.....	.....	.....	.....
126	15.58	14.65	0.93	2, 4	.....	+29	+23	.....	−19	− 2
127	14.35	13.31	1.04	6, 11	.....	+65	+51	.....	+14	+26

TABLE IX—*Continued*

No.	Magnitude		Color Index	No. Obs.	MW *Minus* HC	MW *Minus* Gr	MW *Minus* Dz	MW *Minus* HH_W	MW *Minus* Gr_1	MW *Minus* Dz_1
	Pg	Pv								
127*a*	16.78	15.81	0.97	4, 1	.....	.....	.....	.....	.....	.....
127*b*	18.40	16.96	1.44	3, 1	.....	.....	.....	.....	.....	.....
127*c*	17.01	15.50	1.51	8, 2	.....	.....	.....	.....	.....	.....
127*d*	18.29	17.05	1.24	2, 2	.....	.....	.....	.....	.....	.....
127*e*	18.24	16.97	1.27	2, 2	.....	.....	.....	.....	.....	.....
128	15.88	13.87	2.01	1, 2	.....	+61	+48	.....	−16	+29
130	15.26	14.21	1.05	2, 9	.....	+63	+57	.....	+12	+32
134	14.43	13.54	0.89	6, 10	.....	+64	+54	.....	+17	+28
134*a*	17.52	16.22	1.30	4, 2	.....	.....	.....	.....	.....	.....
134*b*	17.96	16.72	1.24	2, 2	.....	.....	.....	.....	.....	.....
139	15.30	13.96	1.34	2, 7	.....	+48	+26	.....	−11	+ 3
142	14.60	13.71	0.89	2, 11	.....	+56	+45	.....	+ 9	+19
143	16.35	15.51	0.84	7, 2	.....	.....	.....	.....	.....	.....
146	14.52	13.56	0.96	2, 10	.....	+70	+56	.....	+21	+31
151	13.72	12.58	1.14	29, 11	.....	+53	+22	.....	− 1	− 2
151*a*	18.66	17.21	1.45	3, 2	.....	.....	.....	.....	.....	.....
151*b*	18.55	17.15	1.40	3, 2	.....	.....	.....	.....	.....	.....
151*c*	18.10	16.88	1.22	3, 2	.....	.....	.....	.....	.....	.....
151*d*	18.21	16.93	1.28	3, 2	.....	.....	.....	.....	.....	.....
151*e*	18.45	17.08	1.37	3, 2	.....	.....	.....	.....	.....	.....
152	14.56	13.76	0.80	21, 12	.....	+45	+31	.....	0	+ 5
152*a*	18.38	16.63	1.75	5, 2	.....	.....	.....	.....	.....	.....
152*b*	17.56	16.74	0.82	7, 2	.....	.....	.....	.....	.....	.....
152*c*	17.15	16.09	1.06	10, 2	.....	.....	.....	.....	.....	.....
152*d*	18.66	17.38	1.28	2, 1	.....	.....	.....	.....	.....	.....
152*e*	18.52	17.12	1.40	2, 2	.....	.....	.....	.....	.....	.....
154	14.95	14.36	0.59	8, 9	.....	+29	+39	.....	−10	+12
154*a*	17.78	16.59	1.19	3, 2	.....	.....	.....	.....	.....	.....
154*b*	18.11	17.04	1.07	4, 1	.....	.....	.....	.....	.....	.....
154*c*	18.40	17.13	1.27	3, 1	.....	.....	.....	.....	.....	.....
158	15.10	14.57	0.53	16, 5	.....	+14	+12	.....	−23	−16
158*a*	18.77	17.09	1.68	3, 2	.....	.....	.....	.....	.....	.....
158*b*	18.88	17.20	1.68	3, 1	.....	.....	.....	.....	.....	.....
159	15.20	14.50	0.70	16, 4	.....	+24	+32	.....	−18	+ 5
159*a*	17.80	16.34	1.46	5, 1	.....	.....	.....	.....	.....	.....
159*b*	18.13	16.64	1.49	5, 2	.....	.....	.....	.....	.....	.....
159*g*	19.03	17.10	1.93	2, 1	.....	.....	.....	.....	.....	.....
160	16.68	15.54	1.14	11, 2	.....	.....	.....	.....	.....	.....
160*a*	18.73	16.95	1.78	3, 2	.....	.....	.....	.....	.....	.....
163	15.13	13.93	1.20	1, 3	.....	+16	− 7	.....	−39	−31
164	16.02	15.03	0.99	18, 5	.....	.....	+11	.....	.....	−14
164*a*	18.73	17.13	1.60	3, 1	.....	.....	.....	.....	.....	.....
169	16.85	16.02	0.83	13, 2	.....	.....	.....	.....	.....	.....
169*a*	18.46	16.95	1.51	6, 2	.....	.....	.....	.....	.....	.....
172	13.85	12.24	1.61	2, 1	.....	+71	+28	.....	+ 5	+ 7
176	14.33	13.81	0.52	36, 12	.....	+26	+26	.....	−11	− 2
176*a*	16.87	16.07	0.80	12, 2	.....	.....	.....	.....	.....	.....
176*c*	18.22	17.15	1.07	3, 2	.....	.....	.....	.....	.....	.....
183	16.53	15.64	0.89	21, 3	.....	.....	.....	.....	.....	.....
184*a*	17.18	16.03	1.15	3, 2	.....	.....	.....	.....	.....	.....
184*b*	17.14	16.14	1.00	3, 2	.....	.....	.....	.....	.....	.....
184*c*	18.52	16.82	1.70	3, 2	.....	.....	.....	.....	.....	.....
186	16.34	15.54	0.80	22, 3	.....	.....	.....	.....	.....	.....

TABLE IX—*Continued*

No.	Magnitude		Color Index	No. Obs.	MW *Minus* HC	MW *Minus* Gr	MW *Minus* Dz	MW *Minus* HH_W	MW *Minus* Gr_1	MW *Minus* Dz_1
	Pg	Pv								
188....	16.29	15.27	1.02	24, 4	.....	+67	+31	.....	+16	+ 6
190*a*...	17.56	16.57	0.99	15, 2	.....	.....	.....	.....	.....	.....
190*b*...	18.10	16.78	1.32	16, 2	.....	.....	.....	.....	.....	.....
190*c*...	17.87	16.95	0.92	12, 2	.....	.....	.....	.....	.....	.....
190*d*...	17.99	16.73	1.26	11, 2	.....	.....	.....	.....	.....	.....
190*f*...	19.19	17.21	1.98	3, 1	.....	.....	.....	.....	.....	.....
191*a*...	19.17	17.53	1.64	3, 1	.....	.....	.....	.....	.....	.....
202....	16.12	15.41	0.71	27, 4	.....	.....	+21	.....	.....	− 6
202*a*...	18.80	17.21	1.59	11, 2	.....	.....	.....	.....	.....	.....
205....	15.97	15.08	0.89	11, 4	.....	+53	+28	.....	+ 6	+ 2
207....	16.69	15.73	0.96	10, 2	.....	.....	.....	.....	.....	.....
208....	16.67	15.93	0.74	12, 2	.....	.....	.....	.....	.....	.....
208*a*...	18.65	17.07	1.58	3, 2	.....	.....	.....	.....	.....	.....
208*b*...	18.69	17.17	1.52	3, 2	.....	.....	.....	.....	.....	.....
212*d*...	17.81	16.88	0.93	17, 2	.....	.....	.....	.....	.....	.....
212*e*...	17.04	16.31	0.73	18, 2	.....	.....	.....	.....	.....	.....
213....	16.81	15.75	1.06	20, 3	.....	.....	.....	.....	.....	.....
214....	15.39	14.66	0.73	9, 7	.....	+22	+23	.....	−21	− 4
214*c*...	18.53	16.79	1.74	3, 2	.....	.....	.....	.....	.....	.....
214*d*...	17.59	16.23	1.36	3, 2	.....	.....	.....	.....	.....	.....
214*e*...	17.88	16.73	1.15	3, 2	.....	.....	.....	.....	.....	.....
214*f*...	18.15	16.47	1.68	3, 2	.....	.....	.....	.....	.....	.....
214*g*...	18.06	16.69	1.37	3, 2	.....	.....	.....	.....	.....	.....
215....	15.47	13.69	1.78	10, 3	.....	+60	+30	.....	−11	+10
217....	16.55	15.51	1.04	10, 4	.....	.....	.....	.....	.....	.....
218....	15.47	14.11	1.36	17, 8	.....	+47	+27	.....	−13	+ 4
218*a*...	16.82	15.59	1.23	12, 4	.....	.....	.....	.....	.....	.....
218*b*...	17.20	16.02	1.18	11, 2	.....	.....	.....	.....	.....	.....
219*a*...	17.61	16.63	0.98	17, 2	.....	.....	.....	.....	.....	.....
219*b*...	17.53	16.20	1.33	17, 2	.....	.....	.....	.....	.....	.....
219*c*...	17.85	16.81	1.04	13, 2	.....	.....	.....	.....	.....	.....
219*d*...	18.69	16.95	1.74	12, 2	.....	.....	.....	.....	.....	.....
219*e*...	19.03	17.50	1.53	9, 1	.....	.....	.....	.....	.....	.....
219*f*...	18.26	16.93	1.33	13, 2	.....	.....	.....	.....	.....	.....
219*g*...	18.53	16.99	1.54	11, 2	.....	.....	.....	.....	.....	.....
219*h*...	19.11	17.50	1.61	3, 1	.....	.....	.....	.....	.....	.....
224....	16.49	15.48	1.01	22, 4	.....	.....	.....	.....	.....	.....
226....	14.93	14.23	0.70	46, 7	.....	+35	+30	.....	− 7	+ 3
226*a*...	18.45	16.79	1.66	10, 2	.....	.....	.....	.....	.....	.....
226*b*...	18.30	16.92	1.38	11, 2	.....	.....	.....	.....	.....	.....
226*c*...	18.73	16.93	1.80	10, 2	.....	.....	.....	.....	.....	.....
226*d*...	18.79	17.11	1.68	11, 1	.....	.....	.....	.....	.....	.....
226*e*...	18.81	17.02	1.79	9, 1	.....	.....	.....	.....	.....	.....
227*a*...	17.69	16.49	1.20	14, 2	.....	.....	.....	.....	.....	.....
227*b*...	18.15	16.99	1.16	12, 2	.....	.....	.....	.....	.....	.....
227*c*...	18.51	17.29	1.22	10, 2	.....	.....	.....	.....	.....	.....
227*d*...	17.93	16.67	1.26	17, 2	.....	.....	.....	.....	.....	.....
229....	16.34	15.57	0.77	24, 3	.....	.....	.....	.....	.....	.....
229*a*...	18.23	16.99	1.24	16, 2	.....	.....	.....	.....	.....	.....
229*b*...	17.80	16.69	1.11	16, 2	.....	.....	.....	.....	.....	.....
244....	16.22	15.47	0.75	13, 4	.....	.....	.....	.....	.....	.....
244*a*...	17.93	16.68	1.25	8, 2	.....	.....	.....	.....	.....	.....
244*b*...	18.75	16.83	1.92	1, 1	.....	.....	.....	.....	.....	.....

TABLE IX—*Continued*

No.	Magnitude		Color Index	No. Obs.	MW *Minus* HC	MW *Minus* Gr	MW *Minus* Dz	MW *Minus* HH_W	MW *Minus* Gr_1	MW *Minus* Dz_1
	Pg	Pv								
247....	16.43	15.89	0.54	21, 2	.....	.....	.....	.....	.....	.....
248*a*...	16.30	15.23	1.07	4, 3	.....	.....	.....	.....	.....	.....
254*a*...	18.71	17.64	1.07	8, 1	.....	.....	.....	.....	.....	.....
256....	14.67	13.86	0.81	50, 11	.....	+56	+29	.....	+11	+ 3
258....	16.07	15.22	0.85	6, 4	.....	+58	+28	.....	+12	+ 2
258*a*...	17.45	16.17	1.28	5, 2	.....	.....	.....	.....	.....	.....
277....	15.30	14.61	0.69	62, 7	.....	+21	+22	.....	−21	− 5
277*a*...	18.54	17.04	1.50	10, 1	.....	.....	.....	.....	.....	.....
279*a*...	17.98	16.87	1.11	7, 2	.....	.....	.....	.....	.....	.....
279*b*...	18.47	17.07	1.40	8, 2	.....	.....	.....	.....	.....	.....
279*c*...	17.73	16.27	1.46	7, 2	.....	.....	.....	.....	.....	.....
279*d*...	18.44	17.21	1.23	6, 2	.....	.....	.....	.....	.....	.....
279*e*...	18.60	16.88	1.72	6, 2	.....	.....	.....	.....	.....	.....
279*f*...	17.80	16.75	1.05	7, 2	.....	.....	.....	.....	.....	.....
283....	14.87	13.50	1.37	28, 3	.....	+54	+21	.....	− 6	− 2
286....	15.97	14.96	1.01	10, 4	.....	+48	.....	.....	− 2	.....
288*a*...	16.63	15.29	1.34	23, 5	.....	.....	.....	.....	.....	.....
288*b*...	18.53	17.45	1.08	13, 2	.....	.....	.....	.....	.....	.....
288*c*...	18.10	16.81	1.29	13, 2	.....	.....	.....	.....	.....	.....
288*d*...	19.06	17.53	1.53	8, 1	.....	.....	.....	.....	.....	.....
289*a*...	17.91	16.84	1.07	12, 2	.....	.....	.....	.....	.....	.....
289*b*...	18.77	17.25	1.52	11, 1	.....	.....	.....	.....	.....	.....
289*c*...	18.76	17.21	1.55	11, 1	.....	.....	.....	.....	.....	.....
289*d*...	17.44	16.29	1.15	14, 2	.....	.....	.....	.....	.....	.....
289*e*...	17.52	16.55	0.97	12, 2	.....	.....	.....	.....	.....	.....
292*a*...	17.96	16.82	1.14	5, 2	.....	.....	.....	.....	.....	.....
292*b*...	17.27	16.16	1.11	5, 2	.....	.....	.....	.....	.....	.....
292*c*...	17.49	16.77	0.72	3, 1	.....	.....	.....	.....	.....	.....
292*d*...	18.82	16.46	2.36	2, 1	.....	.....	.....	.....	.....	.....
295....	15.57	14.93	0.64	32, 5	.....	+31	+23	.....	− 9	− 4
295*a*...	17.97	16.95	1.02	14, 2	.....	.....	.....	.....	.....	.....
295*b*...	18.09	16.88	1.21	13, 2	.....	.....	.....	.....	.....	.....
295*c*...	18.85	17.53	1.32	10, 1	.....	.....	.....	.....	.....	.....
295*d*...	19.26	17.68	1.58	3, 1	.....	.....	.....	.....	.....	.....
297....	15.81	14.79	1.02	5, 3	.....	+41	+17	.....	−10	− 8
297*a*...	18.56	17.11	1.45	2, 1	.....	.....	.....	.....	.....	.....
297*b*...	18.10	16.93	1.17	3, 1	.....	.....	.....	.....	.....	.....
299....	16.59	15.83	0.76	22, 2	.....	.....	.....	.....	.....	.....
301....	16.23	15.57	0.66	26, 2	.....	.....	+12	.....	.....	−15
302*a*...	16.91	15.97	0.94	21, 2	.....	.....	.....	.....	.....	.....
302*b*...	18.24	16.89	1.35	14, 2	.....	.....	.....	.....	.....	.....
302*c*...	19.02	17.50	1.52	9, 1	.....	.....	.....	.....	.....	.....
302*d*...	18.97	17.33	1.64	6, 1	.....	.....	.....	.....	.....	.....
311....	15.00	14.36	0.64	53, 7	.....	+30	+32	.....	−10	+ 5
311*a*...	17.22	16.05	1.17	14, 2	.....	.....	.....	.....	.....	.....
311*b*...	17.73	16.68	1.05	5, 2	.....	.....	.....	.....	.....	.....
319....	14.44	13.55	0.89	40, 3	.....	+49	+29	.....	+ 2	+ 3
323*a*...	17.55	16.55	1.00	17, 2	.....	.....	.....	.....	.....	.....
323*b*...	18.96	17.17	1.79	8, 1	.....	.....	.....	.....	.....	.....
323*c*...	18.66	17.01	1.65	10, 2	.....	.....	.....	.....	.....	.....
323*e*...	18.81	17.18	1.63	10, 2	.....	.....	.....	.....	.....	.....
323*f*...	18.90	17.05	1.85	10, 1	.....	.....	.....	.....	.....	.....

TABLE IX—*Continued*

No.	Magnitude		Color Index	No. Obs.	MW *Minus* HC	MW *Minus* Gr	MW *Minus* Dz	MW *Minus* HH_W	MW *Minus* Gr_1	MW *Minus* Dz_1
	Pg	Pv								
323*h*	19.03	17.08	1.95	8, 1	.....	.....	.....	.....	.....	.....
324*a*	17.95	16.72	1.23	17, 2	.....	.....	.....	.....	.....	.....
324*b*	18.57	17.05	1.52	13, 2	.....	.....	.....	.....	.....	.....
329	14.32	13.34	0.98	38, 3	.....	+47	+31	.....	− 2	+ 6
334	15.20	14.42	0.78	70, 7	.....	+30	+20	.....	−14	− 6
335	16.11	15.11	1.00	23, 4	.....	+35	.....	.....	−15	.....
335*a*	17.69	16.67	1.02	13, 2	.....	.....	.....	.....	.....	.....
335*b*	18.77	17.33	1.44	7, 1	.....	.....	.....	.....	.....	.....
336	14.92	13.97	0.95	26, 5	.....	+42	+27	.....	− 7	+ 2
336*a*	17.31	16.27	1.04	5, 2	.....	.....	.....	.....	.....	.....
336*b*	17.27	16.41	0.86	5, 2	.....	.....	.....	.....	.....	.....
337*a*	18.50	16.84	1.66	14, 2	.....	.....	.....	.....	.....	.....
337*c*	18.82	17.38	1.44	11, 2	.....	.....	.....	.....	.....	.....
337*d*	18.98	17.34	1.64	10, 1	.....	.....	.....	.....	.....	.....
338	14.72	13.79	0.93	28, 3	.....	+45	+28	.....	− 3	+ 3
341	15.16	13.92	1.24	26, 3	.....	+36	+25	.....	−20	+ 1
342	14.86	14.09	0.77	26, 3	.....	+24	+27	.....	−20	+ 1
343	16.44	15.01	1.43	23, 5	.....	.....	.....	.....	.....	.....
343*a*	17.94	16.83	1.11	16, 2	.....	.....	.....	.....	.....	.....
343*b*	18.86	17.27	1.59	9, 1	.....	.....	.....	.....	.....	.....
343*c*	17.16	16.59	0.57	17, 2	.....	.....	.....	.....	.....	.....
343*d*	18.46	16.89	1.57	10, 2	.....	.....	.....	.....	.....	.....
343*e*	18.56	16.95	1.61	11, 2	.....	.....	.....	.....	.....	.....
345	13.79	12.01	1.78	58, 11	.....	+66	+17	.....	− 5	− 3
350	11.01	10.64	0.37	46, 12	.....	+37	+40	.....	+ 4	+11
350*a*	17.39	16.59	0.80	8, 1	.....	.....	.....	.....	.....	.....
350*b*	17.72	16.79	0.93	5, 2	.....	.....	.....	.....	.....	.....
350*c*	18.19	16.64	1.55	5, 2	.....	.....	.....	.....	.....	.....
358	15.22	14.11	1.11	26, 2	.....	+23	+15	.....	−30	− 9
362	13.13	12.31	0.82	86, 12	.....	+53	+31	.....	+ 8	+ 5
362*a*	16.39	15.61	0.78	19, 2	.....	.....	.....	.....	.....	.....
362*b*	17.47	16.57	0.90	15, 2	.....	.....	.....	.....	.....	.....
362*c*	18.15	16.48	1.67	13, 2	.....	.....	.....	.....	.....	.....
362*d*	17.96	16.75	1.21	14, 2	.....	.....	.....	.....	.....	.....
362*e*	18.47	16.99	1.48	11, 2	.....	.....	.....	.....	.....	.....
362*f*	18.78	17.23	1.55	10, 2	.....	.....	.....	.....	.....	.....
362*h*	18.74	17.29	1.45	10, 2	.....	.....	.....	.....	.....	.....
363*a*	17.94	16.41	1.53	14, 2	.....	.....	.....	.....	.....	.....
363*b*	18.36	17.05	1.31	13, 1	.....	.....	.....	.....	.....	.....
364	16.44	15.49	0.95	22, 3	.....	.....	.....	.....	.....	.....
364*a*	17.20	16.35	0.85	17, 2	.....	.....	.....	.....	.....	.....
364*b*	18.01	16.99	1.02	12, 1	.....	.....	.....	.....	.....	.....
364*c*	16.88	16.11	0.77	17, 1	.....	.....	.....	.....	.....	.....
364*d*	17.55	16.71	0.84	13, 1	.....	.....	.....	.....	.....	.....
364*e*	18.24	16.82	1.42	10, 1	.....	.....	.....	.....	.....	.....
364*f*	18.54	17.24	1.30	10, 1	.....	.....	.....	.....	.....	.....
364*i*	18.39	17.05	1.34	10, 1	.....	.....	.....	.....	.....	.....
365*c*	18.85	17.11	1.74	11, 1	.....	.....	.....	.....	.....	.....
365*d*	19.04	17.20	1.84	6, 1	.....	.....	.....	.....	.....	.....
365*e*	18.97	17.34	1.63	9, 1	.....	.....	.....	.....	.....	.....
368	15.78	14.48	1.30	2, 3	.....	+46	+24	.....	−12	+ 1
368*a*	17.17	16.09	1.08	1, 1	.....	.....	.....	.....	.....	.....

TABLE IX—*Continued*

No.	Magnitude		Color Index	No. Obs.	MW *Minus* HC	MW *Minus* Gr	MW *Minus* Dz	MW *Minus* HH_w	MW *Minus* Gr_1	MW *Minus* Dz_1
	Pg	Pv								
370*c*	16.80	15.73	1.07	22, 1	.....	.....	.....	.....	.....	.....
372	16.09	15.52	0.57	10, 3	.....	.....	.....	.....	.....	.....
372*a*	17.40	16.62	0.78	3, 1	.....	.....	.....	.....	.....	.....
372*b*	17.82	16.63	1.19	5, 2	.....	.....	.....	.....	.....	.....
372*c*	17.31	16.69	0.62	4, 1	.....	.....	.....	.....	.....	.....
378	14.14	12.74	1.40	54, 5	.....	+ 68	+20	.....	+ 7	− 3
386*c*	18.17	16.77	1.40	12, 1	.....	.....	.....	.....	.....	.....
386*e*	17.72	16.85	0.87	15, 1	.....	.....	.....	.....	.....	.....
389	13.57	12.83	0.74	43, 8	.....	+ 47	+32	.....	+ 4	+ 5
391	14.63	13.85	0.78	38, 6	.....	+ 48	+42	.....	+ 4	+16
401	14.53	13.61	0.92	36, 3	.....	+ 43	+26	.....	− 5	+ 1
403	14.51	13.75	0.76	41, 3	.....	+ 29	+25	.....	−15	− 1
410*a*	16.96	16.18	0.78	17, 1	.....	.....	.....	.....	.....	.....
424	14.51	13.64	0.87	29, 3	.....	+ 38	+38	.....	− 8	+12
426	13.83	13.33	0.50	28, 3	.....	+ 47	+29	.....	+10	+ 1
427	13.27	12.07	1.20	33, 5	.....	+ 62	+35	.....	+ 7	+11
439	15.29	13.49	1.80	1, 3	.....	+118	+89	.....	+46	+69

show the mean results for these two methods of reducing the intensity. The deviations are in all cases referred to the mean scale, which depends upon 42 separate determinations.

As the lower limit of Table XI is only 17.1, some indication of the accordance of the results for the faint stars is desirable. This is shown in Table XII, which gives the mean deviations of groups of stars for each of the long-exposure plates. In no case is there a serious divergence from the mean scale. Some of the average deviations at the bottom of the table appear to be large; but it must be recalled that they include the errors of the scales derived from the separate plates for a range of 9 or 10 magnitudes. The number of magnitudes from each plate and the diaphragms used for the reduced-intensity exposures are also shown at the bottom of the table.

Although the photo-visual results are based upon a much smaller number of plates than the photographic, their relative weights are more nearly equal than the number of observations would indicate. This arises from the higher precision of the individual magnitudes from the photo-visual plates. Thus the average deviation of a single photographic magnitude, based on the results for stars fainter than the tenth magnitude and including the effect of

TABLE X

RECTANGULAR CO-ORDINATES FOR 1900

No.	X	Y	No.	X	Y	No.	X	Y
119*a*	−755″	− 79″	219*a*	−329″	−181″	302*d*	+230″	−339″
125*a*	−750	−446	219*b*	−304	−156	311*a*	+193	−549
127*a*	−695	+ 36	219*c*	−332	−312	311*b*	+171	−703
127*b*	−664	− 76	219*d*	−270	−160	323*a*	+178	+242
127*c*	−651	− 70	219*e*	−254	−168	323*b*	+163	+214
127*d*	−670	−101	219*f*	−288	−214	323*c*	+118	+254
127*e*	−667	−112	219*g*	−322	−240	323*e*	+245	+194
134*a*	−649	−365	219*h*	−342	−285	323*f*	+268	+190
134*b*	−697	−280	226*a*	−311	+251	323*h*	+288	+228
151*a*	−544	− 93	226*b*	−357	+208	324*a*	+207	− 6
151*b*	−625	− 35	226*c*	−211	+196	324*b*	+162	+ 78
151*c*	−636	− 7	226*d*	−172	+174	335*a*	+247	−524
151*d*	−619	0	226*e*	−228	+286	335*b*	+296	−599
151*e*	−607	+ 17	227*a*	−268	−412	336*a*	+187	−820
152*a*	−608	−252	227*b*	−209	−394	336*b*	+210	−788
152*b*	−608	−321	227*c*	−178	−402	337*a*	+289	− 62
152*c*	−619	−234	227*d*	−206	−265	337*c*	+248	− 87
152*d*	−630	−258	229*a*	−243	− 73	337*d*	+248	− 31
152*e*	−622	−364	229*b*	−231	− 85	343*a*	+302	−465
154*a*	−538	−574	244*a*	−181	−599	343*b*	+301	−460
154*b*	−478	−530	244*b*	−200	−685	343*c*	+328	−468
154*c*	−536	−580	248*a*	− 80	−954	343*d*	+362	−506
158*a*	−524	−316	254*a*	− 79	−292	343*e*	+354	−455
158*b*	−556	−277	258*a*	−140	−791	350*a*	+335	−685
159*a*	−648	+145	277*a*	− 78	−571	350*b*	+240	−710
159*b*	−543	+171	279*a*	+ 45	−690	350*c*	+283	−755
159*g*	−505	+233	279*b*	− 94	−645	362*a*	+482	−352
160*a*	−536	+ 57	279*c*	− 57	−691	362*b*	+487	−194
164*a*	−531	−199	279*d*	− 39	−712	362*c*	+466	−182
169*a*	−520	− 31	279*e*	+ 49	−693	362*d*	+457	−154
176*a*	−487	−210	279*f*	+ 84	−682	362*e*	+455	−224
176*c*	−415	−333	288*a*	− 2	−240	362*f*	+486	−276
184*a*	−460	−649	288*b*	+ 27	−254	362*h*	+372	−310
184*b*	−422	−836	288*c*	+ 70	−288	363*a*	+351	+ 4
184*c*	−409	−633	288*d*	+ 89	−210	363*b*	+398	+101
190*a*	−432	+152	289*a*	+ 42	+186	364*a*	+458	−462
190*b*	−364	+137	289*b*	− 35	+193	364*b*	+503	−481
190*c*	−452	+169	289*c*	− 28	+224	364*c*	+542	−460
190*d*	−449	+261	289*d*	+ 2	+353	364*d*	+488	−554
190*f*	−376	+150	289*e*	+ 51	+311	364*e*	+548	−511
191*a*	−392	−146	292*a*	− 20	−854	364*f*	+452	−513
202*a*	−355	− 22	292*b*	+109	−780	364*i*	+540	−377
208*a*	−376	−434	292*c*	+ 52	−912	365*c*	+410	−115
208*b*	−346	−395	292*d*	+122	−836	365*d*	+384	−138
212*d*	−227	+130	295*a*	+ 68	−530	365*e*	+374	−185
212*e*	−333	+196	295*b*	+ 37	−489	368*a*	+413	−796
214*c*	−241	−833	295*c*	+ 26	−429	370*c*	+311	+215
214*d*	−310	−849	295*d*	+ 11	−406	372*a*	+443	−691
214*e*	−358	−830	297*a*	+100	−914	372*b*	+411	−692
214*f*	−345	−783	297*b*	+102	−905	372*c*	+416	−721
214*g*	−352	−768	302*a*	+162	−286	386*c*	+472	+ 52
218*a*	−278	−515	302*b*	+164	−270	386*e*	+531	− 56
218*b*	−320	−595	302*c*	+224	−264	410*a*	+577	−247

scale errors, is ±0.125 magnitude; the corresponding photo-visual result is ±0.087. From this it follows that the accordance of the separate photo-visual scales must be even better than that of the results in Table XII. A discussion of the residuals proves this to be the case.

IX. COMPARISONS WITH OTHER MAGNITUDES

The reference of the Mount Wilson photographic magnitudes to the international zero point introduces a large systematic difference into the comparison with *H.C.*, No. 170. Between the tenth and

TABLE XI

SYSTEMATIC DIFFERENCES FOR VARIOUS APERTURES (UNIT=0.01 MAG.)

MEAN MAG.	*G*	*g*	32	14	8.6	*S*	MEANS	
							Screens	Diaphragms
11.4	+9.6	+8.4	−1.3	−1.6	−2.8	+11.1	+9.4	−1.6
12.7	−0.6	+2.6	−0.8	+1.3	−0.8	+ 5.0	+0.3	−0.8
13.7	−2.2	+6.2	−0.2	+0.7	−2.5	+ 0.9	+0.7	−1.2
14.2	−2.4	+4.8	+0.6	+0.8	−0.3	− 6.4	−0.8	+0.6
14.8	−5.3	−0.4	+0.7	+0.7	+1.9	− 5.9	−4.3	+0.8
15.2	−5.2	−1.7	−0.2	+0.9	+3.0	− 4.8	−4.5	+0.6
15.5	−7.5	−1.5	−0.8	+2.1	+2.5	− 8.5	−6.2	+0.7
16.4	−8.2	−0.2	−0.4	+1.9	+5.1	−16.2	−5.4	+1.4
17.1	−7.3	−0.2	+1.9	−0.4	+2.8	.....	−4.5	+1.1
No. scales	5	2	17	10	5	3	7	32
No. values	423	156	2326	1654	507	227	579	4487

the sixteenth magnitudes this is nearly constant. Below this region there is a divergence which rapidly increases and, for the faintest stars given, amounts to about one magnitude. The faintest magnitude given in *H.C.*, No. 170, is 21.00; the faintest here shown is about 20.

Although some modification of the scale of *H.C.*, No. 170, has been made by Miss Leavitt in her final discussion of the data,[1] the changes are not great. They affect the divergence for the bright stars only slightly, and that for the faint ones not at all. A detailed comparison with the Harvard scale is reserved for a later paper, but it may be remarked here that the divergence at the lower end of

[1] *Harvard Annals*, **71**, Part III, 1914.

the scale is to be attributed to differences in the methods of reduction. The explanation of that for the bright stars is less obvious,

TABLE XII

SYSTEMATIC DEVIATIONS OF LONG-EXPOSURE PLATES (UNIT=0.01 MAG.)

Mean Mag.	769	788	795	808	196	200	204	230	232	235
11.1	+21	−26	−11	−24	− 4	+11	+15	+ 4	− 9	+26
12.2	+ 2	−22	−17	− 6	−23	+ 6	+10	− 4	0	+15
13.2	+ 4	− 1	−10	+ 7	− 5	− 2	− 7	+ 2	− 1	+11
13.7	− 7	+ 4	0	+10	−18	+ 4	−13	−11	+ 4	+12
14.1	− 4	0	+ 1	+ 2	+ 6	+ 3	+ 3	−11	+ 4	− 2
14.6	+ 1	+ 6	+ 1	− 6	− 2	+ 5	− 7	− 3	+ 4	−12
15.1	− 2	+ 7	+ 2	+ 4	+ 7	− 2	+ 9	+ 4	+ 2	− 9
15.6	+ 2	−12	+ 1	+16	+10	− 2	− 3	+ 3	+ 1	+ 9
16.1	+ 5	−12	0	+ 7	+14	+ 7	− 1	+ 6	− 4	0
16.6	+15	− 6	+ 2	+ 6	− 1	+12	− 7	− 2	−11	− 7
17.1	+19	+ 5	+ 4	− 7	− 5	+ 8	−14	− 6	−19	− 4
17.6	+15	− 4	+ 7	− 3	−11	+ 9	−12	− 4	−12	0
18.1	+ 8	−12	+ 9	0	− 2	+ 2	+ 2	− 6	−18	+ 5
18.6	+25	+27	.....	.....	+ 6	−10	+16	− 7	−10	+13
19.1	.....	.....	.....	.....	+22	−13	.....	− 4	− 7	+18
19.6	.....	.....	.....	.....	.....	−30	.....	.....	.....	.....
A.D.	14.7	15.6	10.6	15.0	14.6	12.7	16.0	11.0	13.5	12.3
No.	181	168	179	154	168	300	170	309	292	294
Ap.	32	32	32	14	6	6	6	14	14	14

Mean Mag.	310	312	313	314	225	229	1343	1347	1550	1561
11.1	+ 2	− 4	−19	+26	.....	+10	+ 3	.....	.....	.....
12.2	+ 1	+15	− 5	+16	.....	− 1	−12	−12	.....	.....
13.2	− 3	+ 6	+ 2	+ 5	.....	− 1	− 2	+ 2	.....	.....
13.7	−10	+11	+ 2	− 7	.....	− 6	+ 9	+ 5	.....	.....
14.1	0	− 4	+ 3	−11	.....	− 2	− 6	− 9	.....	.....
14.6	− 1	+ 7	+11	− 8	− 7	− 1	+ 6	− 8	.....	.....
15.1	+ 5	− 6	+ 2	−15	− 5	+ 1	+ 2	+ 2	.....	+13
15.6	+ 4	− 5	−13	−13	+ 4	+ 9	+ 1	+ 4	+ 4	−14
16.1	− 1	+ 4	− 3	−14	+ 8	+ 4	− 2	− 1	− 2	+ 3
16.6	+ 3	+ 8	− 1	− 7	+ 2	− 5	0	+ 5	.....	−22
17.1	+ 5	+ 8	+ 5	+ 5	− 2	− 1	− 1	+ 3	0	−10
17.6	+ 2	+ 4	+11	+ 9	− 5	+ 2	− 1	− 4	+15	− 7
18.1	+ 8	+ 4	+ 9	+ 9	− 4	− 1	− 6	− 7	+ 9	− 2
18.6	+14	+ 1	+ 4	+15	− 3	− 5	− 7	−10	+ 2	− 4
19.1	+12	0	− 1	+10	−17	−14	+25	+ 2	+16	0
19.6	.....	.....	.....	.....	−14	.....	.....	+32	+28	+ 8
A.D.	13.3	13.5	12.3	14.1	12.7	10.7	11.2	11.9	14.8	12.1
No.	277	307	281	333	323	354	253	267	181	179
Ap.	14	14	14	32	60	60	60	60	60	60

although some information is afforded by a re-reduction of the Harvard plates by methods which could not well be employed in the initial discussion of the data.

Since the zero points for the results by Chapman and Melotte and by Dziewulski depend upon the magnitudes of *H.C.*, No. 170, they, too, show large systematic differences when compared with the final Mount Wilson scale. Here again the differences are nearly constant, so that for the region in question the four scales are sensibly parallel; but the agreement becomes even better when it is noted that each of the three series of differences is affected by a more or less pronounced color equation.

By plotting the differences MW−HC, MW−Gr, and MW−Dz against color indices, the following relations were found:

$$\begin{aligned} \text{MW}-\text{HC} &= +0.30+0.15\,C \\ \text{MW}-\text{Gr} &= +0.23+0.27\,C \\ \text{MW}-\text{Dz} &= +0.31-0.06\,C \end{aligned}$$

in which C represents the color index.

The first of these, which is derived from the values of MW−HC for magnitudes 10–15, is a mean result and does not necessarily apply to any given star. The magnitudes of *H.C.*, No. 170, are based upon data obtained with many different instruments, among them the 60-inch reflector at Mount Wilson, and the results enter in varying proportions into the final magnitudes. Although reductions to a standard system were made in the case of stars known to be red, the HC results are not altogether homogeneous, for the colors of the fainter stars, many of which are also red, were not then known. In consequence, each star requires a special correction for color. Moreover, the corrections decrease in amount with increasing magnitude, for with the fainter objects the influence of the Mount Wilson observations entering into the HC results becomes increasingly predominant. The detailed determination of these corrections which reduce the differences to the system of the reflector will be given later. The results, however, appear in Table IX under the heading $\text{MW}-\text{HH}_\text{w}$.[1]

[1] The symbol HH_w designates the magnitude system of *H.C.*, No. 170, after the application of the following corrections: (*a*) corrections to complete the reduction to the standard color system adopted by Miss Leavitt; (*b*) a zero-point correction of +0.08 mag. applied in her final discussion in *H.A.*, **71**, Part III; (*c*) a color correction which refers the results to the color system of the Mount Wilson reflector. The addition of (*a*) and (*b*) to the results of *H.C.*, No. 170, gives what may be called the Harvard Homogeneous Scale (HH). The further application of (*c*) gives the system HH_w. Details of this part of the discussion will appear in *Mt. Wilson Contr.*, No. 98.

The corrected differences for Gr and Dz are similarly shown under the headings $MW-Gr_1$ and $MW-Dz_1$. For these the color equations given above, including the constant term, have been used as they stand.

With the exception of the beginning and ending of the $MW-HH_w$ series, the residuals are very satisfactory, at least for all cases including any considerable number of observations. The parallelism of all four scales is now very good between the ninth and the sixteenth magnitudes.

TABLE XIII

COMPARISON OF SCALES FOR BRIGHT STARS

STAR No.	PHOTOGRAPHIC				PHOTO-VISUAL			
	MW	MW−G	MW−V	MW−HH$_w$	MW	MW−P	MW−Y	MW−HC
1S	2.54	.....	(−31)	−25	2.08	− 4	−12	− 4
1	4.39	− 1	− 8	−16	4.37	−13	−13	− 7
2	5.30	+10	+ 7	− 1	5.28	+10	− 5	−10
3	5.83	+ 7	+ 8	− 1	5.56	− 7	− 7	− 6
4	5.91	− 7	−12	− 8	5.84	− 7	+ 2	− 2
5	6.45	− 5	− 6	− 2	6.47	− 4	− 7	+ 4
2S	6.45	0	0	− 2	6.33	+ 2	+17	+ 5
1r	6.61	−11	−16	−26	5.09	+10	+ 5	−17
3S	6.64	− 1	+ 2	− 1	6.35	+ 6	+14	+ 2
6	7.11	− 9	− 5	+ 4	7.05	− 4	0	+ 4
7	7.41	+ 7	+11	+16	7.52	+ 1	− 2	+ 8
2r	7.94	+ 9	−13	+ 3	6.35	+ 7	+ 3	−20
Z.P. correction		+ 6	+47			−19	+ 9	

Since the zero-point reduction for the Mount Wilson photo-visual magnitudes is only 0.03, the differences in the last column of Table VIII show with sufficient exactness the relation of the final values to the visual magnitudes of *H.C.*, No. 170. As already remarked, there is here also an appreciable color equation, the agreement for the red stars being noticeably better than for the white.

There remains still to be noted a comparison of the Mount Wilson results with those of Parkhurst, Müller and Kempf, and Schwarzschild. The differences are shown in Table XIII alongside the corresponding values of $MW-HH_w$. To facilitate the comparison, the Göttingen, Yerkes, and Potsdam magnitudes have received the zero-point corrections which appear at the bottom of the table.

In addition, the Yerkes photographic magnitudes have been multiplied by 0.94.[1] There is some evidence that the Yerkes photo-visual magnitudes require a similar correction, but as the case is not altogether clear, no change has been made in the slope of the scale.

X. COLOR OF THE STARS

One of the most interesting results of the investigation is the series of color indices given in Table IX. Attention has already been called to the gradual change in the minimum color index with increasing magnitude.[2] The additional data now available only confirm in all essential particulars the results previously found. At the seventeenth magnitude (photo-visual) the smallest color index appears to be 0.7 or 0.8 mag. The change with increasing magnitude is approximately linear.

SUMMARY

The paper deals with the determination of absolute scales of photographic and photo-visual magnitude within the intervals 2.5–20.0 and 2.0–17.5, respectively. With diaphragms and screens scales were first established for the stars of intermediate brightness. These were then extended in both directions to include both bright and faint stars. The results give photographic and photo-visual magnitudes for 617 and 339 objects, respectively, of which 311 appear in both groups. For these color indices are therefore available. The relation between color index and magnitude previously announced is confirmed.

The internal accordance of the results is satisfactory. With due allowance for color, the photographic scale agrees well from the ninth to the sixteenth magnitude with results found at Harvard, Greenwich, and Potsdam. It also agrees well with the Yerkes and Göttingen magnitudes of bright stars, for which values between 4.4 and 7.9 are available. The divergence from the scale of *H.C.*, No. 170, below the sixteenth magnitude is due to differences of reduction. That for the bright stars has been decreased by the

[1] *Vierteljahrsschrift der Astron. Gesellschaft*, **47**, 356, 1913.

[2] *Mt. Wilson Contr.*, No. 81; *Astrophysical Journal*, **39**, 361, 1914.

correction for color, but there are still important differences which will be considered in *Mt. Wilson Contr.*, No. 98.

The photo-visual scale agrees well with other determinations in the region of the bright stars, and coincides with the visual scale of *H.C.*, No. 170, at the twelfth magnitude. For intermediate points, the comparison with the latter scale is less satisfactory and shows the influence of color.

MOUNT WILSON SOLAR OBSERVATORY
January 16, 1915

PARALLAXES OF FOUR VISUAL BINARIES

By FREDERICK SLOCUM

The parallaxes of the following binaries have been determined from photographs made with the 40-inch refractor of the Yerkes Observatory. The methods of exposure, measurement, and reduction have been explained in this *Journal* by F. Schlesinger in Vols. **32, 33,** and **34,** and by F. Slocum and S. A. Mitchell in **38,** 1, 1913.

42 α Comae Berenices ($13^h5^m, +18°3'$)

This is a short-period binary, 25.3 years, with a large proper motion, 0".49 per year. The plane of the orbit is nearly in the line of sight so that the position angle is practically constant at about 190°, the two stars almost, if not actually, making an occultation at intervals of about 13 years. The components are of equal magnitude, 5.2, and the distance is always less than 1".0.

TABLE 1

PLATES OF 42 α COMAE BERENICES

No.	Date	Hour Angle	Observers	Quality of Images
1094	1913 Feb. 1	-1^h1	Su, Sl	Fair
1107	Feb. 6	−1.1	Su, M	Fair
1117	Feb. 8	−0.6	Sl	Good
1127	Feb. 9	−0.3	Su, M	Fair
1225	May 18	+0.4	Sl	Good
1230	May 31	+1.3	Su, M	Poor
1236	June 1	+0.6	Su, Sl	Poor
1499	1914 Feb. 15	−0.3	Su, Sl	Fair
1500	Feb. 15	+0.3	Su, Sl	Fair
1505	Feb. 26	+0.5	Su, Sl	Good
1588	May 17	+0.3	Su, Sl	Fair
1590	May 24	+0.5	Su, Sl	Good
1593	May 30	+0.2	Su, Sl	Good

Sl = Slocum, Su = Sullivan, M = Mitchell, V = Van Maanen, L = Lee.

During the period covered by my plates, 1913–1914, the distance was so small that the stars could not be separated on the plates and the measures were made upon the center of the system.

The tables give the data for the plates and their reductions. Unless otherwise noted, values are in terms of scale-divisions. 1 division = 2″.66.

COMPARISON STARS

No.	Diameter	X (Right Ascension)	Y (Declination)	Dependence
	mm			
1	0.23	−279	+257	+0.061
2	.11	−257	+ 56	+ .197
3	.35	−210	−123	+ .310
4	.16	+159	−205	+ .268
5	.14	+250	− 11	+ .107
6	.16	+337	+ 26	+0.057
Parallax star	0.26	− 43.9	− 66.2	

The mean magnitude of the comparison stars is about 10.7.

TABLE 2

REDUCTIONS FOR 42 α COMAE BERENICES

Plate	Solution (m)	Weight (p)	Parallax Factor (P)	Time in Days (t)	Residual (v)	$\sqrt{p}\,v$ in Arc
1094	+0.464	0.7	+0.825	−226	−0.013	−0″.03
1107	.468	0.7	+ .788	−221	− .006	− .01
1117	.477	0.7	+ .772	−219	+ .004	+ .01
1127	.490	0.7	+ .763	−218	+ .018	+ .04
1225	.393	0.7	− .598	−120	− .007	− .02
1230	.406	0.4	− .741	−107	+ .015	+ .03
1236	.384	0.4	− .750	−106	− .006	− .01
1499	.308	0.7	+ .710	+153	.000	.00
1500	.316	0.7	+ .709	+153	+ .008	+ .02
1505	.294	1.0	+ .587	+164	− .007	− .02
1588	.248	0.7	− .582	+244	+ .008	+ .02
1590	.231	1.0	− .665	+251	− .004	− .01
1593	+0.232	1.0	−0.728	+257	+0.001	0.00

The normal equations are:

$$9.4\,c + 2.6900\,\mu + 0.9685\,\pi = +3.2878$$
$$+38.6329\,\mu - 5.7863\,\pi = -0.8536$$
$$+4.6894\,\pi = +0.7045$$

from which

$$c = +0.3601$$
$$\mu = -0.0439 = -0''.117$$
$$\pi = +0.0217 = +0''.058 \pm 0''.008$$

Probable error corresponding to unit weight, $\pm 0.0055 = \pm 0''.015$.

2 η Coronae Borealis ($15^h19^m, +30°39'$)

This system has already described more than two revolutions, so that the period is very accurately known. According to Lohse it is 41.6 years. The components are of 5.6 and 6.1 magnitudes, and their distance varies from about $0''.04$ to nearly $1''.0$. They are not separated on the plates, and settings were made on the center of the composite image.

TABLE 1

PLATES OF 2 η CORONAE BOREALIS

No.	Date	Hour Angle	Observers	Quality of Images
698	1912 Mar. 17	$-0^h.6$	Sl,	Good
711	Mar. 21	−0.8	Su, Sl	Poor
786	June 15	−0.3	Su, M	Fair
789	June 22	−.01	Su, M	Good
1111	1913 Feb. 6	+.01	Su, M	Poor
1120	Feb. 8	−.03	Su, Sl	Good
1121	Feb. 8	+0.3	Su, Sl	Fair
1130	Feb. 9	+0.2	Su, M	Fair
1139	Feb. 12	−1.0	Su, Sl	Poor
1143	Feb. 16	−0.2	Su, M	Good
1257	June 12	−0.1	Su, Sl	Fair
1262	June 21	0.0	Su, M	Poor
1268	June 22	+0.2	Su, Sl	Fair
1289	July 3	+0.1	Su, Su	Fair

COMPARISON STARS

No.	Diameter	*X* (Right Ascension)	*Y* (Declination)	Dependence
	mm			
1	0.11	−300	−219	+0.221
2	.18	−150	+162	+ .247
3	.12	+196	−211	+ .254
4	.19	+254	+268	+0.278
Parallax star	0.32	+ 16.9	+ 12.3	.....

The mean magnitude of the comparison stars is about 12.0.

TABLE 2

REDUCTIONS FOR 2 η CORONAE BOREALIS

Plate	Solution (m)	Weight (p)	Parallax Factor (P)	Time in Days (t)	Residual (v)	$\sqrt{p}\cdot v$ in Arc
698	−0.147	0.7	+0.787	−287	+0.013	+0″.03
711	.114	0.4	+ .748	−283	+ .047	+ .08
786	.180	0.7	− .525	−197	− .002	− .01
789	.203	1.0	− .618	−190	− .024	− .06
1111	.103	0.4	+ .951	+ 39	− .015	− .03
1120	.097	1.0	+ .953	+ 41	− .010	− .03
1121	.114	0.7	+ .953	+ 41	− .027	− .06
1130	.083	0.7	+ .954	+ 42	+ .004	+ .01
1139	.082	0.4	+ .954	+ 45	+ .004	+ .01
1143	.079	1.0	+ .950	+ 49	+ .007	+ .02
1257	.106	0.7	− .479	+105	− .005	− .01
1262	.058	0.4	− .602	+174	+ .044	+ .07
1268	.107	0.7	− .615	+175	− .005	− .01
1289	−0.088	0.7	−0.744	+186	+0.016	+0.03

The normal equations are:

$$9.5\,c - 0.2250\,\mu + 2.3371\,\pi = -1.0993$$
$$+23.7695\,\mu - 1.4937\,\pi = +0.4834$$
$$+5.9994\,\pi = -0.1515$$

from which

$$c = -0.1220$$
$$\mu = +0.0209 = +0''.056$$
$$\pi = +0.0275 = +0''.073 \pm 0''.014$$

Probable error corresponding to unit weight, $\pm 0.0117 = \pm 0''.031$.

70 Ophiuchi ($18^h0^m + 2°31'$)

This system has a very large proper motion, 1″.13 per year. It has recently completed one revolution since the date of discovery, its period being 87.9 years. The components are of 4.3 and 6.0 magnitudes and vary from about 1″.5 to 6″.5 in distance. They are clearly separated on the plates, but the companion is so much reduced by the occulting disk that on many of the plates its image is too weak for accurate measurement. The accompanying data, therefore, apply to the brighter star only.

TABLE 1

PLATES OF 70 OPHIUCHI

No.	Date	Hour Angle	Observers	Quality of Images
247	1910 Apr. 10	-1^h1	Su, Sl	Poor
410	1911 Apr. 22	−0.6	Su, Sl	Good
468	Aug. 19	+1.0	Su, Sl	Poor
880	1912 Sept. 7	+1.0	Su, M	Fair
1335	1913 Aug. 2	+0.6	Su, M	Good
1340	Aug. 16	+1.0	Su, Su	Poor
1341	Aug. 17	+0.2	Su, Su	Fair
1555	1914 Apr. 9	−0.4	Sl, L	Fair
1572	Apr. 25	−0.6	Su, L	Fair

COMPARISON STARS

No.	Diameter	X (Right Ascension)	Y (Declination)	Dependence
	mm			
1	0.18	−344	−198	+0.169
2	.19	−299	+255	+ .155
3	.16	0	−194	+ .173
4	.14	+ 20	+190	+ .161
5	.18	+263	−245	+ .178
6	.31	+360	+192	+0.164
Parallax star	0.26	+ 4.6	− 9.2	.....

The mean magnitude of the comparison stars is about 10.5.

TABLE 2

REDUCTIONS FOR 70 OPHIUCHI

Plate	Solution (m)	Weight (p)	Parallax Factor (P)	Time in Days (t)	Residual (v)	$\sqrt{p}\,v$ in Arc
247	−0.027	0.4	+0.940	−928	−0.010	−0″.02
410	.021	1.0	+ .854	−551	+ .004	+ .01
468	.148	0.4	− .836	−432	+ .012	+ .02
880	.177	0.7	− .972	− 47	− .005	− .01
1335	.153	1.0	− .652	+282	− .006	− .02
1340	.152	0.4	− .812	+296	+ .008	+ .01
1341	.161	0.7	− .822	+297	.000	.00
1555	.032	0.7	+ .945	+532	− .011	− .03
1572	−0.017	0.7	+0.824	+548	+0.013	+0.03

The normal equations are:

$$\begin{aligned} 6.0\,c + \quad 2.3640\,\mu - 0.0987\,\pi &= -0.5757 \\ +130.8917\,\mu - 4.2594\,\pi &= -0.6006 \\ +4.2859\,\pi &= +0.3526 \end{aligned}$$

from which

$$\begin{aligned} c &= -0.0945 \\ \mu &= -0.0003 \quad = -0''.001 \\ \pi &= +0.0798 = +0''.212 \pm 0''.007 \end{aligned}$$

Probable error corresponding to unit weight, $\pm 0.0055 = \pm 0''.015$.

The m's in the foregoing table have been corrected for orbital motion by the data given in Boss's *Preliminary General Catalogue*, p. 275.

A reduction using the uncorrected values of m yielded

$$\pi = +0''.209 \pm 0''.008$$

85 Pegasi (23^h56^m, $+26°34'$)

According to Burnham this is "one of the most important and most interesting of the known binary systems. The shortness

TABLE 1

PLATES OF 85 PEGASI

No.	Date	Hour Angle	Observers	Quality of Images
584	1911 Dec. 15	-0^h1	Sl, V	Good
588	Dec. 18	−0.2	Sl, V	Good
826	1912 July 21	−0.2	Su, M	Fair
847	Aug. 4	−0.2	Su, M	Poor
976	Nov. 2	−0.1	Su, Sl	Good
989	Nov. 10	−0.2	Su, Sl	Fair
999	Nov. 16	+0.3	M, Su	Good
1013	Nov. 24	−0.1	Su, Sl	Poor
1017	Nov. 28	+0.2	Su, Sl	Good
1050	Dec. 28	+0.1	Sl, Sl	Fair
1321	1913 July 20	−0.3	M, Su	Poor
1323	July 24	−0.8	Su, M	Good
1324	July 24	−0.2	Su, M	Good
1328	July 26	−1.0	Su, M	Good

COMPARISON STARS

No.	Diameter	*X* (Right Ascension)	*Y* (Declination)	Dependence
	mm			
2	0.16	−341	+274	+0.116
3	.21	+ 3	−257	+ .091
4	.21	+153	+210	+ .519
5	.16	+185	−227	+0.274
Parallax star	0.22	+ 90.9	+ 55.0	.....

The mean magnitude of the comparison stars is about 10.9.

of its period, the rapid movement in space of both components, the relative nearness of this system to our own, and the extreme inequality in magnitude, and closeness of the stars, all combine to give this a leading place among the binary stars."

The proper motion is 1″.3 per year, and the period 25.4 years.

The components are of magnitudes 5.8 and 11.0 and are always less than 1″.0 apart.

The brighter component only appears on the plates.

TABLE 2

REDUCTIONS FOR 85 PEGASI

Plate	Solution (m)	Weight (p)	Parallax Factor (P)	Time in Days (t)	Residual (v)	$\sqrt{p}\cdot v$ in Arc
584	−0.066	1.0	−0.897	−348	−0.006	−0″.01
588	− .066	1.0	− .901	−345	− .008	− .02
826	+ .164	0.7	+ .808	−129	− .003	− .01
847	+ .198	0.4	+ .678	−115	+ .024	+ .04
976	+ .212	1.0	− .597	− 25	+ .008	+ .02
989	+ .227	0.7	− .685	− 17	+ .019	+ .04
999	+ .222	1.0	− .743	− 11	+ .011	+ .03
1013	+ .214	0.4	− .807	− 3	− .001	.00
1017	+ .220	1.0	− .834	+ 1	+ .002	+ .01
1050	+ .215	0.7	− .894	+ 31	− .024	− .05
1321	+ .442	0.4	+ .818	+235	− .013	− .02
1323	+ .448	1.0	+ .786	+239	− .009	− .02
1324	+ .462	1.0	+ .786	+239	+ .005	+ .01
1328	+0.456	1.0	+0.769	+241	−0.002	−0.01

The normal equations are:

$$11.3\,c - 0.4270\,\mu - 1.8951\,\pi = +2.6538$$
$$+45.3106\,\mu + 11.6876\,\pi = +3.8494$$
$$+ 7.1043\,\pi = +0.6882$$

from which

$$c = +0.2431$$
$$\mu = +0.0791 = +0''.210$$
$$\pi = +0.0316 = +\mathbf{0''.084} \pm 0''.010$$

Probable error corresponding to unit weight, $\pm 0.0075 = \pm 0''.020$.

SUMMARY OF RESULTS

Star	B.D. Number	Spectrum	Proper Motion	Relative Parallax	Probable Error	Number of Plates	Probable Error of One Plate	Number of Comp. Stars
42 Comae ..	+18°.2697	F5	0''.49	+**0''.058**	+0''.008	13	±0''.015	6
η Coronae.	+30.2653	G	0.23	+ **.073**	.014	14	.031	4
70 Ophiuchi	+ 2.3482	K	1.13	+ **.212**	.007	9	.015	6
85 Pegasi...	+26.4734	G	1.30	+**0.084**	±0.010	14	±0.020	4

From the foregoing may be obtained the absolute parallax, cross-velocity, motion in space, mass, and luminosity of each system, together with the elements of the orbits, the radial velocities, and the magnitudes, as shown in Tables A and B.

TABLE A

	Galactic Latitude	Mean Mag. of Comp. Stars	Mean Parallax of Comp. Stars	Absolute Parallax of Binaries	Period (P)	Semi-Major Axis (a)	Cross-Velocity
42 Comae	+79°.6	10.7	+0''.004	+**0''.062**	25.3y	0''.67	37.5 km
η Coronae	+56.4	12.0	.003	**.076**	41.6	0.89	14.3
70 Ophiuchi	+11.6	10.5	.004	**.216**	87.9	4.56	24.8
85 Pegasi.....	−35.0	10.9	0.004	+**0.088**	25.4	0.81	70.0

TABLE B

	Radial Velocity	Magnitudes		Mass of System ⊙ = 1	Motion in Space Relative to ⊙	Luminosity ⊙ = 1	
		A	B			A	B
42 Comae	−20.8 km	5.2	5.2	**1.97**	43 km	2.3	2.3
η Coronae....	− 9.7	5.6	6.1	**0.94**	17	1.1	0.7
70 Ophiuchi....	− 7.4	4.3	6.0	**1.22**	26	0.4	0.1
85 Pegasi.....	−31	5.8	11.0	**1.21**	77	0.7	0.006

The mean parallaxes of the comparison stars are taken from Kapteyn's table in *Groningen Publications*, No. 24. The absolute parallaxes of the binaries are simply their relative parallaxes plus the weighted mean parallaxes of the comparison stars.

The masses, in terms of the mass of the sun, were computed from the formula

$$M = \frac{a^3}{\pi^3 P^2},$$

where a is the angular semi-major axis, π the absolute parallax, and P the period in years.

The "absolute magnitude" of a star, as defined by Kapteyn, is the magnitude it would appear to have if placed at such a distance that its parallax would be one-tenth of a second of arc. This is expressed in terms of the observed magnitude m by the equation

$$M = m + 5 + 5 \log \pi .$$

If the sun's apparent stellar magnitude is taken as -26.5, its absolute magnitude on this scale would be 5.1, and the relative brightness of a star and the sun if placed at the same distance, or the luminosity of the star in terms of the sun, may be obtained from the formula

$$\log l_s = -\frac{4}{10}(M_s - 5.1),$$

in which l_s and M_s represent the luminosity and absolute magnitude of the star.

For the first two stars there are no data for determining the relative masses of the components. If we assume them to be equal, in the case of 42 Comae, each is 0.98 of the mass of the sun and 2.3 times as bright. The components of η Coronae are of the order of half the mass of our sun, while A is a trifle brighter and B somewhat fainter than the sun.

The following values of the mass-ratio of the components of 70 Ophiuchi have been published:

$\frac{B}{A}$	
4.0	(Prey)
1.0	(Comstock)
0.5	(Lau)
0.82	(Boss)

These are so discordant that little reliance can be placed upon the individual masses. If, however, we use the mean, 1.6, for the ratio of masses in connection with the mass of the system $1.22\odot$, obtained above, we get the mass of $A=0.47\odot$ and $B=0.75\odot$, whereas A is four times as bright as B, and each is fainter than the sun, their luminosities being $A=0.4\odot$ and $B=0.1\odot$.

For 85 Pegasi the following ratios of masses have been obtained:

$\frac{B}{A}$

1.6 (Comstock)
4.0 (Furner)
3.0 (Lewis)
4.5 (Bowyer and Furner)
2.7 (Bowyer and Furner)
1.0 (Boss)

Here again there is great discrepancy, but it is to be noted that all computers make B, the fainter component, more massive than A. The mean is $B=2.8\,A$ in mass, while A is nearly 100 times as bright as B. Using the foregoing ratio and $1.21\odot$ for the mass of the system, $A=0.3\odot$ and $B=0.9\odot$ in mass, whereas in luminosity $A=0.7\odot$ and $B=0.006\odot$.

The cross-velocities are expressed in terms of kilometers per second, and are obtained by the formula

$$V_c=4.74\frac{\mu}{\pi},$$

where μ is the annual proper motion and π the parallax.

The radial velocities are to be considered only as approximations. Definitive results have not been published for any of these stars. Of the values given, that for 42 Comae is from unpublished results obtained by Lee at the Yerkes Observatory; for η Coronae, Lee, *Astrophysical Journal*, **32**, 304, 1910; for 70 Ophiuchi, Campbell, *ibid.*, **29**, 227, 1909; for 85 Pegasi, Frost, *ibid.*, **25**, 63, 1907.

The motion in space is obtained simply by combining the radial and cross components.

MIDDLETOWN, CONN.
February 26, 1915

Minor Contributions and Notes

THE RADIAL VELOCITIES OF STARS OF CLASS Md

The radial velocities of 24 long-period variable stars of class Md have been determined with a one-prism spectrograph[1] attached to the $37\frac{1}{2}$-inch reflector of the Detroit Observatory. The fact

TABLE I

Star	Harvard Class Md.	Epoch of Obs. 1914	Obs. Radial Velocity		No. of Plates	Residual Velocity* Bright Lines
			Bright Lines	Dark Lines		
001755 T Cassiopeiae	8	Nov.	− 27 km	.....	1	− 20 km
012502 R Piscium.....	7	Nov.	− 58	.....	2	− 64
021024 R Arietis.....	4	Sept.	+101	.....	3	+ 96
021403 o Ceti.....	9	Dec.	+ 53	.....	2	.....
			(+ 48)†	(+63)	.....	+ 38
094211 R Leonis.....	10	Feb.	+ 1	+30	7−2	− 7
103769 R Urs. Maj....	8	May	+ 25	.....	1	+ 32
123160 T Urs. Maj....	6	May	−107	.....	3	− 98
132422 R Hydrae.....	0	May	− 23	.....	1	− 21
134440 R Can. Ven....	9	June	− 21	.....	2	− 9
142530 V Boötis.....	7	May	− 34	.....	1	− 20
151731 S Cor. Bor.....	9	Apr.	− 21	.....	1	− 5
154615 R Serpentis	8	Apr.	+ 7	+33	3−1	+ 24
164715 S Herculis	6	Aug.	− 22	.....	2	− 3
171401 Z Ophiuchi....	0	June	− 92	.....	3	− 74
180531 T Herculis	3	Sept.	−130	.....	3	−110
181136 W Lyrae.....	0	July	−185	.....	3	−165
183308 X Ophiuchi....	8	Nov.	− 91	.....	1	− 72
193311 RT Aquilae....	9	July	− 54	.....	3	− 36
194048 RT Cygni.....	5	Sept.	−127	.....	4	−109
194632 χ Cygni.....	6	Nov.	− 17	.....	2	.....
			(− 21)†	(0)	.....	− 3
205923 R Vulpeculae..	6	June	− 17	.....	3	− 2
210868 T Cephei.....	9	Nov.	− 30	.....	2	− 17
231425 W Pegasi.....	8	July	− 35	.....	3	− 28
235350 R Cassiopeiae .	8	Sept.	+ 9	+35	6−2	+ 17

* On the assumption that the sun is approaching the point $\alpha = 270°0'$, $\delta = +28°0'$, with a speed of 20.0 km per second.

† The values in parentheses are by other observers: those for o Ceti by Campbell and Stebbins, *Lick Observatory Bulletins*, **2**, 78, 1903; those for χ Cygni by Eberhard, *Astrophysical Journal*, **18**, 198, 1903.

The dark-line velocities by the writer are preliminary and may be changed somewhat, but not materially, by the final reductions.

[1] *Publications of the Astronomical Observatory of the University of Michigan*, **1**, 37, 1912.

that the spectra contain strong bright lines makes it possible to observe faint stars photographically, with reasonable exposure times. The exposure for a star of this class, of magnitude 8.5, usually need not exceed two hours, provided the only requirement is good images of the stronger bright lines. Frequently, under these circumstances, the continuous spectrum is very weak or invisible.

The velocities, in most cases, depend on the bright hydrogen lines, particularly Hγ and Hδ. Nearly all the bright lines appear monochromatic, and hence are accurately measurable. The spectra will be further described, and details of the observations recorded, in the *Publications of the Detroit Observatory*.

In no instance does the velocity appear to be variable. However, practically all the observations were secured near the epoch of light-maximum. It is intended to extend the observations to other stars, and to study the spectra of certain stars more exhaustively, but it does not seem probable that many, if indeed any, of this group of stars will prove to be spectroscopic binaries.

The mean of the figures in the last column is -27 km. This may indicate that the radial velocity from the bright lines is systematically in error by that amount. Possibly that derived from the absorption lines is more nearly correct. The discrepancy between the velocities given by the bright and dark lines of stars of this class, discovered by Campbell in *o* Ceti[1], and by Eberhard in χ Cygni,[2] exists also in the cases of R Leonis, R Serpentis, and R Cassiopeiae. Table II contains all the instances known to the writer.

TABLE II

DIFFERENCE OF RADIAL VELOCITY FROM BRIGHT AND DARK LINES

Star	Bright − Dark	
o Ceti	−15 km	(Campbell)
R Leonis	−29	
R Serpentis	−26	
χ Cygni	−21	(Eberhard)
R Cassiopeiae	−26	
Mean	−23 km	

[1] *Lick Observatory Bulletins*, **2**, 78, 1903.

[2] *Astrophysical Journal*, **18**, 198, 1903.

The mean discrepancy between "Bright minus Dark," −23 km, agrees closely enough with the mean residual velocity, −27 km, to support the inference that the bright lines are displaced to the violet about 0.4 A by other causes than radial motion. However, the bright lines usually appear monochromatic, and one would not expect such a displacement, but might be more inclined to believe that they occupy their normal positions, save for Doppler effects, and that the absorption lines, presumably originating in a lower level of the star's atmosphere,[1] are displaced to the red by pressure. From the data at hand, this assumption would lead us to believe that, as a class, the Md stars are approaching the sun, which, again, seems unlikely. Observations in the southern skies would be useful in their bearing on this question.

The arithmetical mean of the residual velocities is 44 km. Applying the correction, +27 km to each velocity, to make the algebraic mean equal to zero, the arithmetical mean is 29 km. Combining this with radial velocities of other objects by Campbell,[2] we have the results given in Table III.

TABLE III

Spectral Types	No.	Average Radial Velocity
O and B	141	9.0 km
A	133	9.9
F	159	13.9
G and K	529	15.2
M	72	16.6
Md (Merrill)	24	29.
Planetary Nebulae	42	46.1

The writer would be glad to learn of any unpublished measures of the bright or dark lines of stars of class Md, which may be in existence at various observatories.

PAUL W. MERRILL

ANN ARBOR, MICH.
January 1915

[1] Though this may well be doubted for the calcium lines.

[2] Taken from *Lick Observatory Bulletins*, **6**, 126, 1911, and from *Proceedings of the National Academy of Sciences*, **1**, 8, 1915.

Reviews

Color-Equation of Various Star Catalogues. By E. C. Pickering. *Annals of Harvard College Observatory*, **76**, No. 2

Beitrag zur Frage nach der Abhängigkeit der Helligkeitsmessungen der Sterne von der Farbe. Von G. Müller und P. Kempf. Abdruck aus den *Astronomischen Nachrichten*, **199**, 89, 1914.

These two valuable contributions to the related problems of magnitude and color in stellar photometry may well be reviewed together. In the former, Professor Pickering has made a comparison of the *Revised Harvard Photometry* with 35 catalogues and parts of catalogues, in such a manner as to show the effect of color on the measures or estimates, and to provide tables for the reduction of the different catalogues to a common standard of color perception. The exceeding usefulness of such a work is evident, but is restricted by the limits of the comparison. The stars used are those of the first *Harvard Photometry* contained in Vol. **14** of the *Annals*, therefore mainly naked-eye stars, numbering not more than 3000 in the Northern Hemisphere. The catalogues compared begin with Hipparchus' and Sufi's stars of the Almagest and include, among others, the photometric catalogues of Seidel, Wolf, Oxford, and Potsdam; the estimates of Heis, Bailey, Herschel, and Argelander, and the various Harvard catalogues from Peirce to Vol. **46**; but excluding the later Vols. **70** and **74** which deal with fainter stars. We are thus for the first time in possession of data for applying the "color-equation" to most of the important catalogues of magnitude.

In Plate I, Fig. 7, it is shown graphically that the *Harvard Photometry* holds a middle position, in regard to color-equation, between the other catalogues; the extremes being Seidel's with an equation of +0.28, and Potsdam with −0.24. The author argues for the universal adoption of the Harvard system from the "fact that nearly all of the other observers agree with the Harvard color-equation within a tenth of a magnitude, and its use in various extensive researches now in progress." The force of this argument is, however, weakened by fact that the author has given as much weight to the estimates of Hipparchus and Sufi as to the *Potsdam Durchmusterung;* and as much to the estimates by Edmunds and by Howard as to Peirce's photometric catalogue. He seems also to have neglected the possible effect of the Purkinje phenomenon, which is considered at length in the second paper to be reviewed.

Müller and Kempf had previously compared the Harvard magnitudes contained in Vol. **14,** observed with the 2-inch meridian photometer, with those in Vol. **44,** observed with the 4-inch instrument, classified according to the estimates of color made at Potsdam. In a range between 2.5 and 6.5 in magnitude, and between white and yellow in color, the equation changed 0.28 magnitude in the direction expected from the Purkinje phenomenon. The appearance of the Harvard Vols. **70** and **74,** containing measures with the 12-inch photometer, led them to make a fresh comparison to see if the same effect was evident with the larger instrument. The results are shown in Table I.

TABLE I

Color	*Harvard Annals*, Vol. 70			*Harvard Annals*, Vol. 74		
	No. of Stars	12-Inch minus 4-Inch	*PD* minus 12-Inch	No. of Stars	12-Inch minus 4-Inch	*PD* minus 12-Inch
		M	M		M	M
W* to GW.....	111	+0.14	+0.15	119	+0.13	+0.18
GW to GW+	164	+0.04	+0.16	169	+0.06	+0.16
WG− to WG+ ...	110	−0.13	+0.13	150	−0.07	+0.14
G−, etc.....	67	−0.17	+0.07	55	−0.16	+0.12
All.....	452	−0.01	+0.14	493	+0.01	+0.15

* W = white, GW = yellowish white, WG = whitish yellow, G = yellow.

The third and sixth columns of the table show the equation between the different apertures used at Harvard. The progression from the white to the yellow stars is well marked in each case and amounts to 0.31 magnitude and 0.29 magnitude, respectively, for the two volumes. The mean values are nearly zero, since the magnitudes from the 4-inch were used as the basis for the 12-inch. The fourth and seventh columns show the progression in the equation between the Harvard 12-inch and the Potsdam measures to be the same in direction but only one-quarter the amount (0.08 magnitude and 0.06 magnitude, respectively) of that between the two Harvard instruments.

The difference in color-perception between Harvard and Potsdam is thus mainly accounted for by the apertures used. The other possible cause suggested by Pickering, the tiring of the eye of the observers in the comparatively leisurely measures at Potsdam, would work in the wrong direction when the measures with the Harvard 12-inch are considered.

J. A. Parkhurst

Yerkes Observatory
January 1915

Astronomy, a Popular Handbook. By HAROLD JACOBY. New York: The Macmillan Co., 1913. 8vo, pp. 435, figs. 124, plates 32. $2.50.

In this book Professor Jacoby follows rather a new plan, both in arrangement and in subject-matter. It is intended to attract the non-scientific reader, and at the same time to serve as a textbook. This is accomplished by introducing very little that is mathematical or technical in the main body of the book. Such material, designed for class use, is reserved for the appendix. A full index makes the book easy for reference.

The opening chapter gives a brief account of the various kinds of celestial objects that make up the universe, and their relations to one another. The chapter is calculated to awaken an interest for the more detailed discussions of the remainder of the book. One of the most commendable chapters is entitled "How to Know the Stars," a topic of much more interest to the general reader than descriptions of astronomical instruments, which subject is reserved for one of the later chapters, and even then little is given that is detailed. The discussions are supplemented by many illustrations and a number of excellent plates.

The work lacks scientific precision in places where more technical statements would add to its value. For instance, reference is made to the use of compound lenses in telescopes, to correct "certain optical imperfections," but no explanation is offered of the imperfections they are to eliminate or of the structure of the lens. A textbook on astronomy seems scarcely complete without such facts, and they could not detract from the interest of the reader possessing a fair understanding of popular scientific truths. There are many instances of redundancy in the style. The book is a step in the direction of popularizing astronomy, and the author's experience as a teacher has enabled him to appreciate points of difficulty and to present facts in an interesting manner.

JESSIE M. SHORT